

FOCUS

A NEW SOLUTION TO **ANTIBIOTIC RESISTANCE**

The superdrugs lurking
in the ocean's depths

PLUS
HOW MUSIC
MAKES US
**FITTER, HAPPIER
AND SMARTER**

SECRETS OF THE DINOSAURS' LAST DAYS

The expedition to discover
how life thrived after impact



Q&A

Why do cats
love catnip?

How far do
sneezes travel?

Why do we
roll our eyes?

**ANIMAL
TO HUMAN
TRANSPLANTS:
HOW CLOSE
ARE WE?**





Christopher
Ward

AUTOMATIC

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WELCOME



For the last three months, a cohort of scientists and engineers afloat off the coast of Mexico have been drilling night and day to dig out cylinders of rock buried beneath the seabed. In June, the team finally struck paydirt – a core of rubble taken from ground zero of the meteorite strike thought to have eradicated the dinosaurs. To find out what this core will tell us about the most cataclysmic event in Earth's history, turn to p34.

These days, humanity is becoming a victim of its own success. Improvements in road and car safety, for one, have meant that the number of organs available to transplant is in steady decline. One solution that scientists are looking at is xenotransplantation – the use of animal organs to replace our own. Turn to p66 to hear bioethicist Michael Reiss's views on the future of animal-to-human transplants.

On p46 we weigh up another ethical dilemma. Psychologically speaking, is it better to be a good or bad person? We asked two psychologists to duke it out, one arguing the case for altruism, the other for selfishness.

And finally, you might have noticed the Olympic Games are coming up. Have you ever wondered how our ancient ancestors, *Australopithecus afarensis*, *Homo erectus* and the like, would have fared against modern humans? Well, we have, so we asked an anthropologist on p56. Enjoy the issue...

Daniel Bennett

Daniel Bennett, acting editor

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ISABELLE DE GROOTE

How would our ancient ancestors have fared at the modern Olympics? Biological anthropologist Isabelle assesses the anatomy and sporting prowess of *Homo erectus*, the Neanderthals and other hominins. → p56



MICHAEL REISS

Michael is a bioethicist and professor of science education at University College London. This month he looks at the controversial idea of using organs from animals to save human lives. → p66



HELEN SCALES

Antibiotics are losing their effectiveness, putting us at risk of diseases and infection. But according to marine biologist Helen, the rivers, lakes and oceans of the world could contain exciting new drugs. → p58

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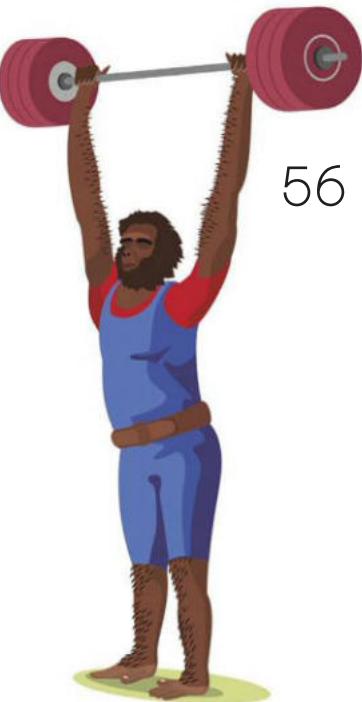
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Could a pig's heart save your life?

66 There is a chronic shortage of donor organs. Could we make up the shortfall with animals, and is it ethically correct to do so?

10 gadgets to upgrade the British summer barbecue

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EYE OPENER

Seeing in the dark

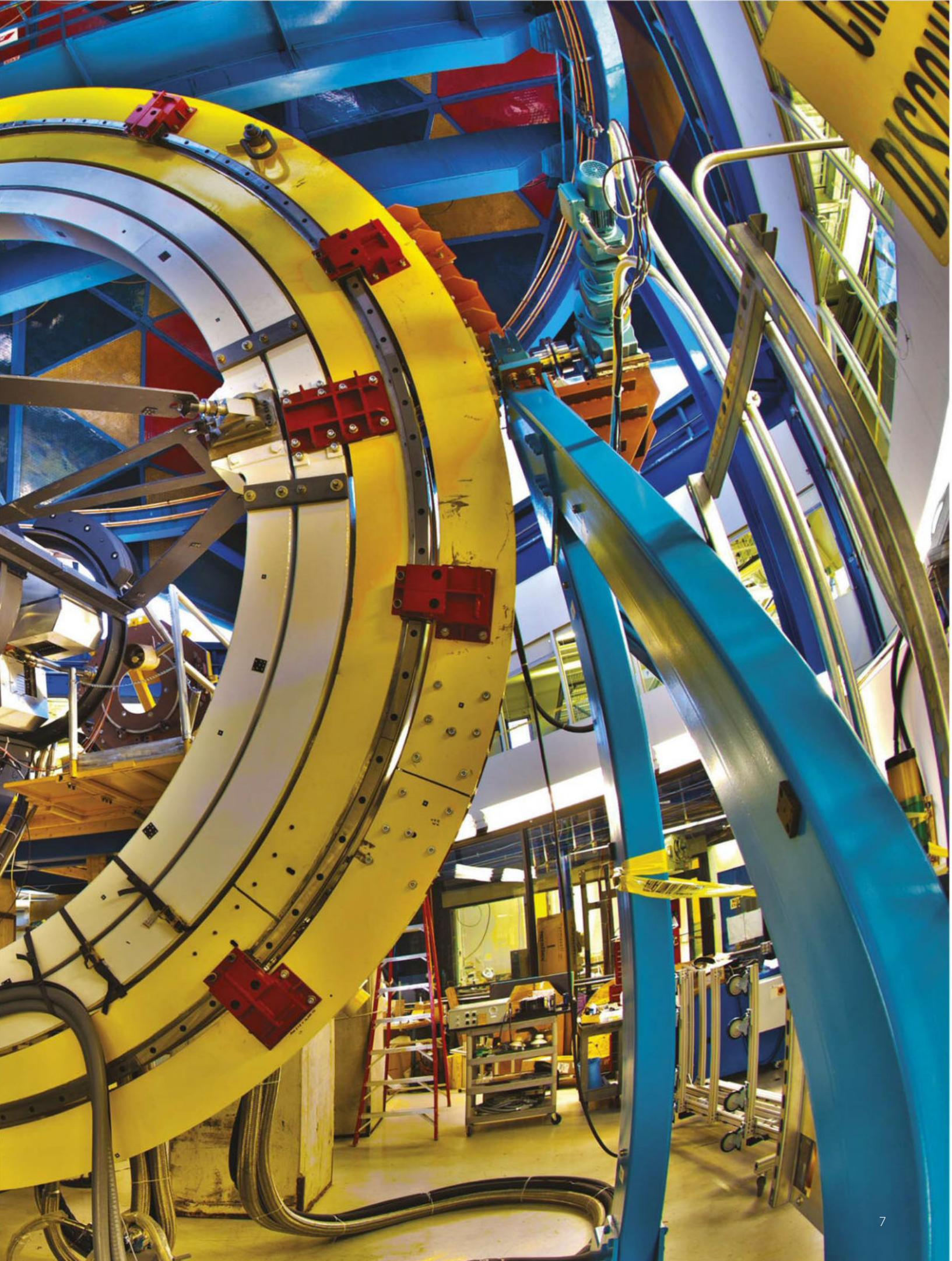
CTI OBSERVATORY,
CHILE

If you're going to solve one of the biggest mysteries in science, you'll need a suitably impressive piece of equipment. This four-tonne digital camera at the Cerro Tololo Inter-American Observatory in Chile is tasked with revealing the nature of dark energy – the little-understood entity that's thought to be accelerating the expansion of the Universe.

The Dark Energy Camera (DECam) boasts 74 CCDs (charge-coupled devices), totalling 570 million pixels. Just like in conventional digital cameras, these convert incoming light into electrical signals. DECam, however, uses specially designed CCDs that are sensitive to the faint, redshifted light emanating from distant galaxies.

The camera is attached to the Victor M Blanco Telescope and has been carrying out a survey of the southern sky since 2013. By 2018, it will have recorded information from 300 million galaxies and thousands of supernovae, helping scientists to measure changes in the Universe's expansion (and dark energy) over the past 14 billion years.

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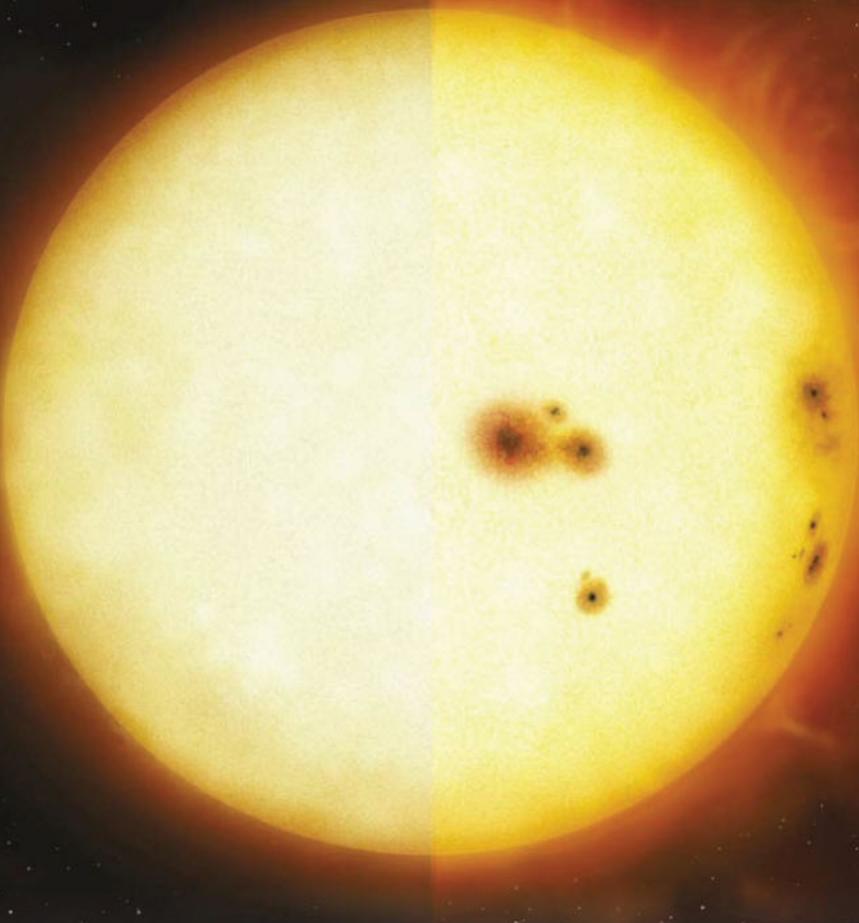
DISCOVERIES

DISPATCHES FROM THE CUTTING EDGE

AUGUST 2016

EDITED BY JASON GOODYER

The Sun undergoes 11-year cycles, where it experiences low activity with few sunspots (left) and high activity with sunspots and solar flares (right)



SUN

SPOT THE DIFFERENCE

As the Sun shows its lowest number of sunspots since 1906, we ask: are we heading for a mini ice age?

In June, something unusual happened: the Sun went blank; that is it lost its spots for the first time in four years. This is a sign that the Sun is approaching a solar minimum, a period where sunspots – darker, cooler areas on the visible surface of the Sun that are caused by intense magnetic activity – are at their least abundant.

Every 11 years, the Sun goes through a cycle during which its magnetic activity fluctuates up and down, leading to changes in the number of sunspots and solar flares. The period of most

activity is called a solar maximum and the period of least activity a solar minimum.

“Solar activity is currently declining from the most recent cycle maximum, which peaked around the end of 2014,” said Prof Joanna Haigh, co-director of the Grantham Institute for Climate Change and Environment.

During a solar maximum, sunspots can erupt, releasing vast amounts of radiation that can disrupt satellites and bombard astronauts with potentially dangerous radiation. During a solar minimum, the lack of solar storms results in Earth losing part of its shield against cosmic radiation coming from outside the Solar System. “Overall, the Sun’s radiation output is reduced at solar minimum so the Earth’s atmosphere shrinks slightly as it is being heated less,” said Prof Lucie Green, author of *15 Million Degrees: A Journey To The Centre Of The Sun*. “This is good news for some satellites and also for the International

SUNSPOT ACTIVITY IS AT ITS
WEAKEST SINCE 1906, WHICH IS
A SIGN IT COULD BE HEADING
TO A LONG-TERM LOW

THE SUN IN NUMBERS

DISTANCE TO EARTH

149,600,000km

Light from the Sun takes eight minutes to reach Earth

RADIUS 695,508km

SURFACE
TEMPERATURE
5,500°C

STAR TYPE
Yellow dwarf

MASS 1.989×10^{30} kg

VOLUME
 1.41×10^{18} km³

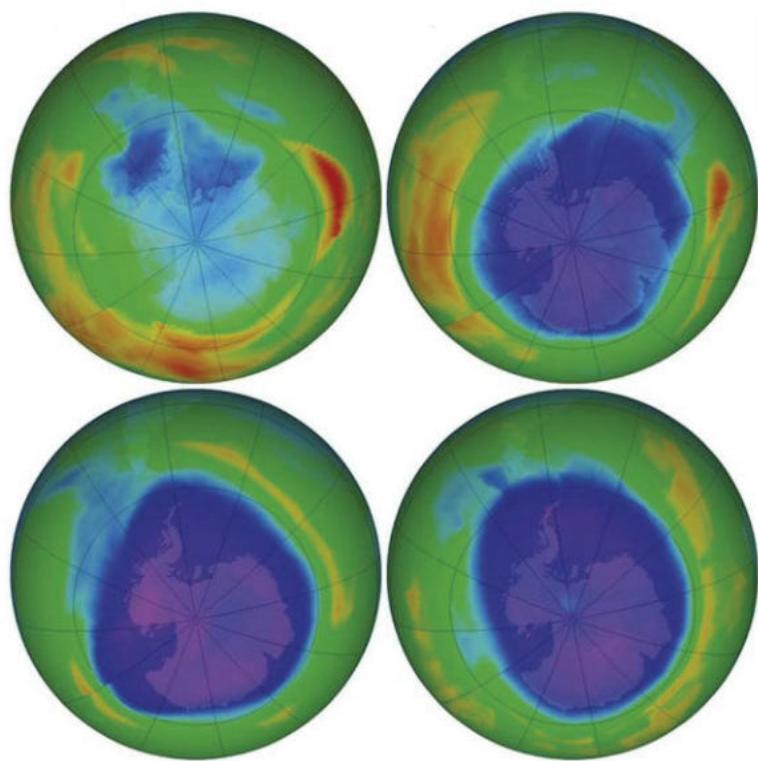
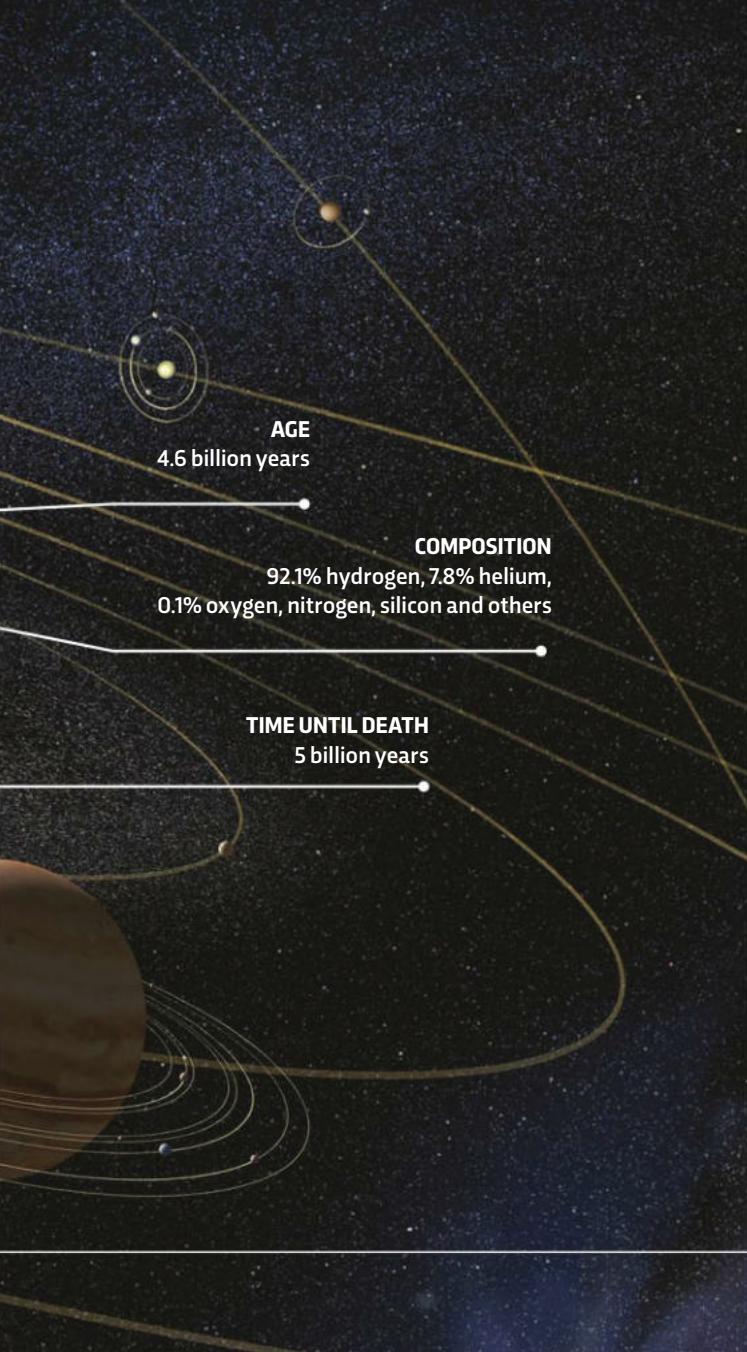
CORE TEMPERATURE
15,000,000°C

Space Station because when the Earth's atmosphere shrinks, these orbiting items experience less drag and so their lifetimes increase. Unfortunately, this is also the case for space debris!"

Sunspot activity is at its weakest since 1906, which is a sign it could be heading to a long-term low that could affect the climate.

"The Sun may be experiencing a longer term decline in activity towards a Grand Minimum," said Haigh. "The last Grand Minimum occurred in the late 17th Century and has been associated with a cooler period in northwestern Europe referred to as the Little Ice Age.

"Our current understanding is that low solar activity at that time had little impact on global temperatures but may have resulted in regional effects, including colder winters in northwestern Europe. Looking ahead we might anticipate the same effects."



Visualisation of the changes in the hole in the ozone layer over Antarctica from 1979 to 2011, moving from purple (low ozone levels) through to blue, green, yellow and orange (high ozone levels)

ENVIRONMENT

Hole in the ozone starts to heal

In 1987, virtually every nation in the world signed the Montreal Protocol. It was a concerted effort to ban the use of CFCs in order to repair the widening hole in Earth's ozone layer. Now, almost 30 years later, it appears to have paid off as scientists at MIT have found evidence that the hole in the ozone layer over the Antarctic is closing.

The team found that the ozone hole has shrunk by more than four million square km, or about half the area of the United States, since 2000, when ozone depletion was at its peak.

"We can now be confident that the things we've done have put the planet on a path to heal," says lead researcher Susan Solomon. "Which is pretty good for us, isn't it? Aren't we amazing humans, that we did something that created a

situation that we decided collectively, as a world, 'Let's get rid of these molecules'? We got rid of them, and now we're seeing the planet respond."

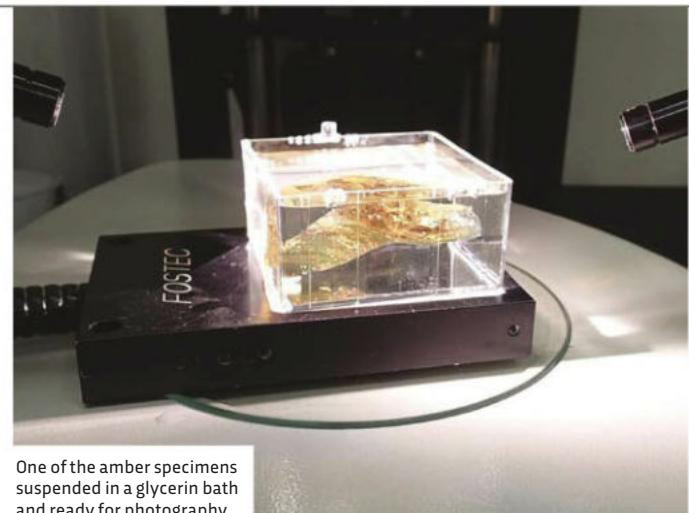
The ozone hole was first discovered in the 1950s. But concerns began to grow in the mid-1980s when scientists from the British Antarctic Survey noticed it was widening.

CFCs (chlorofluorocarbons), chemical compounds once emitted by dry-cleaning processes, refrigerators, and aerosol sprays, were thought to be the main culprit because the chlorine they emit into the atmosphere eats away at ozone.

According to Solomon, if levels of chlorine in the atmosphere continue to dissipate at the current rate, the ozone hole could be closed by the middle of the century.



The feathers can clearly be seen on this image. A claw is marked with an arrow



The tiny bird probably died when it became trapped in sticky tree sap

PALAEONTOLOGY

BIRD WINGS FROM THE TIME OF THE DINOSAURS FOUND TRAPPED IN AMBER

It's two birds in one stone. Two pairs of wings belonging to hatchlings that lived alongside dinosaurs 100 million years ago have been found in Myanmar by an international research team.

The fossilised wings have been immaculately preserved in amber. Each is just two or three centimetres long and includes bones, long 'fingers' tipped with sharp claws, as well as individual feathers.

"These fossil wings show amazing detail," said researcher Mike Benton. "The individual feathers show every filament and whisker, whether they are flight feathers or down feathers, and there are even traces of colour – spots and stripes."

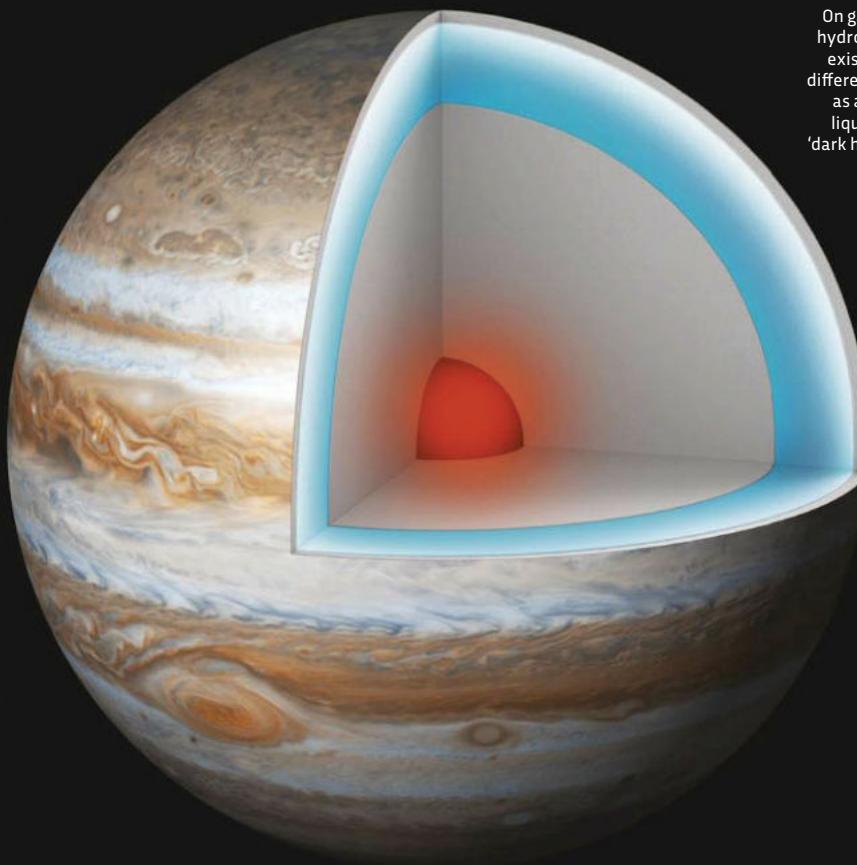
The anatomy of the hand indicates that the fossils come from enantiornithines, a

major group of birds that died out at the same time as the dinosaurs, 66 million years ago. It is likely that the birds wandered out of their nest before becoming trapped in the sticky tree sap that eventually solidified to form amber.

"The fact that the tiny birds were clambering about in the trees suggests that they had advanced development, meaning they were ready for action as soon as they hatched," said lead researcher Dr Xing Lida. "These birds did not hang about in the nest waiting to be fed, but set off looking for food, and sadly died – perhaps because of their small size and lack of experience. Isolated feathers in other amber samples show that adult birds might have avoided the sticky sap, or pulled themselves free."

SPACE

MYSTERIOUS 'DARK HYDROGEN' MAY BE LURKING INSIDE GAS GIANTS



On gas giants, hydrogen may exist in three different forms: as a gas, as a liquid and as 'dark hydrogen'

Does the Solar System have a dark secret?
Researchers at the University of Edinburgh have found that 'dark hydrogen' may be hidden under the surface of gas giant planets such as Jupiter and Saturn.

It is accepted that hydrogen exists as a gas on the surface of giant planets and as liquid metal at their core. But what lies in between?

To investigate this, the team used a laser-heated diamond anvil to recreate conditions found in the interior of gas giants. They squeezed hydrogen to pressures up to 1.5 million times of that on the Earth's surface and heated it up to 5,000°C. They found a point between the

gas and liquid phases at which the hydrogen doesn't absorb or reflect light, which they dubbed 'dark hydrogen'.

"A dark hydrogen layer in giant planets separates the atmosphere and the metallic interior, and neither reflects nor transmits visible light, but does allow infrared radiation to pass," said researcher Stewart Williams. "This indicates heat can easily escape from within giant planets. The dark hydrogen layer also weakly conducts electricity, allowing it to participate in the production of the planetary magnetic field."

The finding may help researchers to understand how gas giants form.

IN NUMBERS

99.999%

The proportion of the Earth's one trillion microbial species yet to be discovered, as estimated by a biologist at Indiana University.

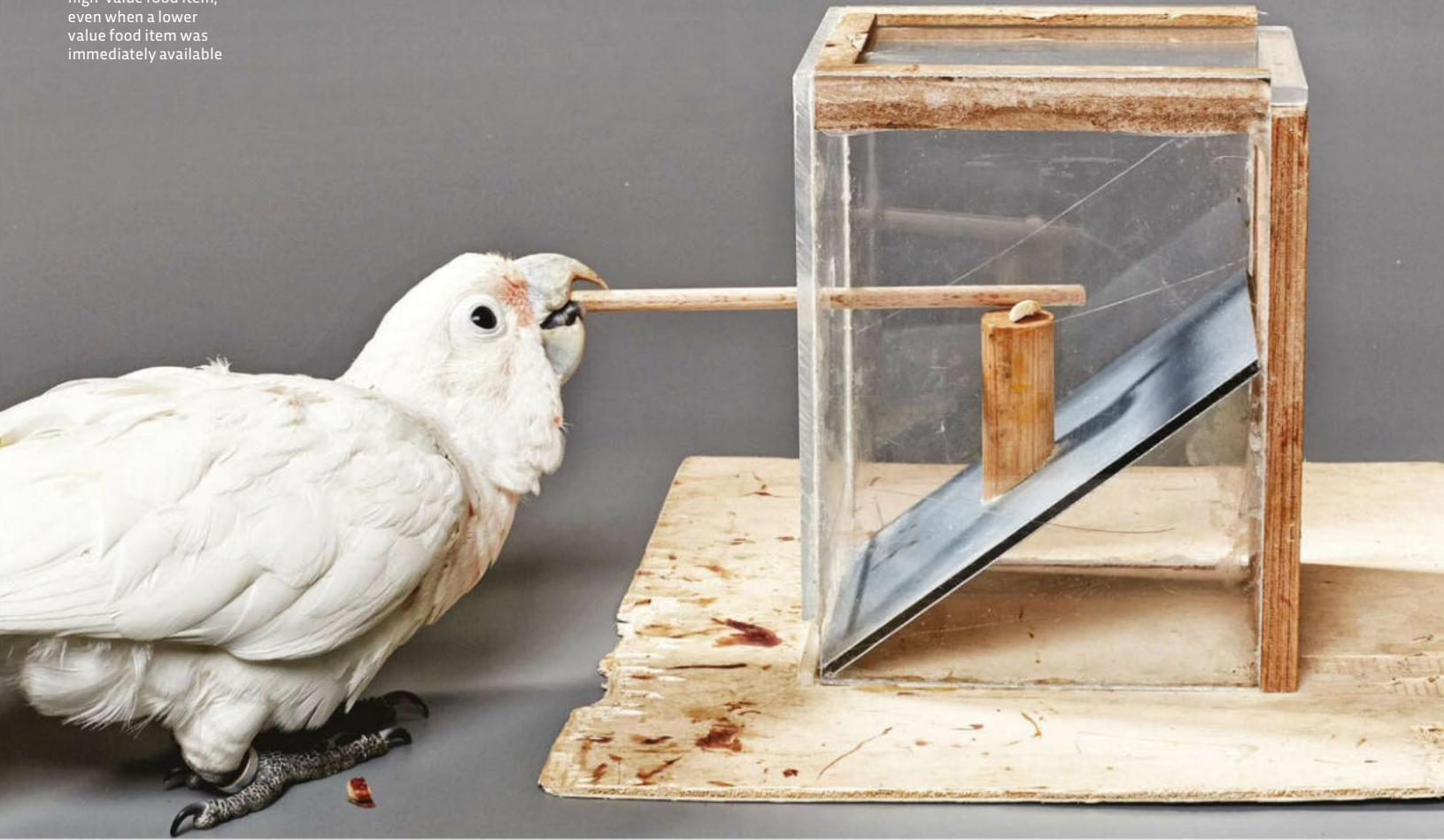
89.5m

The height of the world's tallest tree: a yellow meranti discovered in the Malaysian rainforest by researchers at Cambridge University.

15 trillion

The number of litres of helium found in a gas field in Tanzania. The discovery will help to combat the world shortage of the gas, which is used in everything from MRI scanners to deep-sea diving equipment.

The cockatoos made the effort to use the tool to reach the high-value food item, even when a lower value food item was immediately available



ZOOLOGY

COCKATOOS MAKE DECISIONS ABOUT TOOL USE

Who's a clever boy, then? Researchers at the University of Vienna have devised a test to show that conscious reasoning is involved in tool use by Goffin's cockatoos, a species native to Indonesia.

The cockatoos prefer cashew nuts to pecans: if the former are available they will disregard the latter. They have also been seen to demonstrate two forms of tool use: using a stick to rake food into reach, and dropping balls into a tube to knock out a reward. In the University of Vienna experiment, cockatoos were presented with a piece of equipment that required a tool to reach the food inside (whether a high-value cashew or a lower value pecan), a food item and a tool.

THEY CHOSE
THE STICK
TOOL
OVER THE
IMMEDIATE
LOWER
VALUE FOOD

"If a lower value food or a high-value food was out-of-reach inside the apparatus and the choice was between a high-value food item and a tool, they chose the food over the tool," said research leader Isabelle Laumer. Yet when the cockatoos had a choice between a low-value food or a tool, they picked the tool but only if it worked for the apparatus. If the wrong tool was provided, they picked the low-value food.

Yet it also seemed as if the cockatoos contemplated the variations in quality between the two rewards. "When the stick apparatus with the high-value food inside was available, they chose the stick tool over the immediate lower value food," she added.

SPACE

YOUNGEST-EVER EXOPLANET DISCOVERED

Ahh... it's only a baby. The Kepler space telescope has found the youngest exoplanet yet discovered. K2-33b is a gas giant around six times the size of Earth that orbits star K2-33 in the Upper Scorpius region, some 500 light-years away, and is no more than 10 million years old.

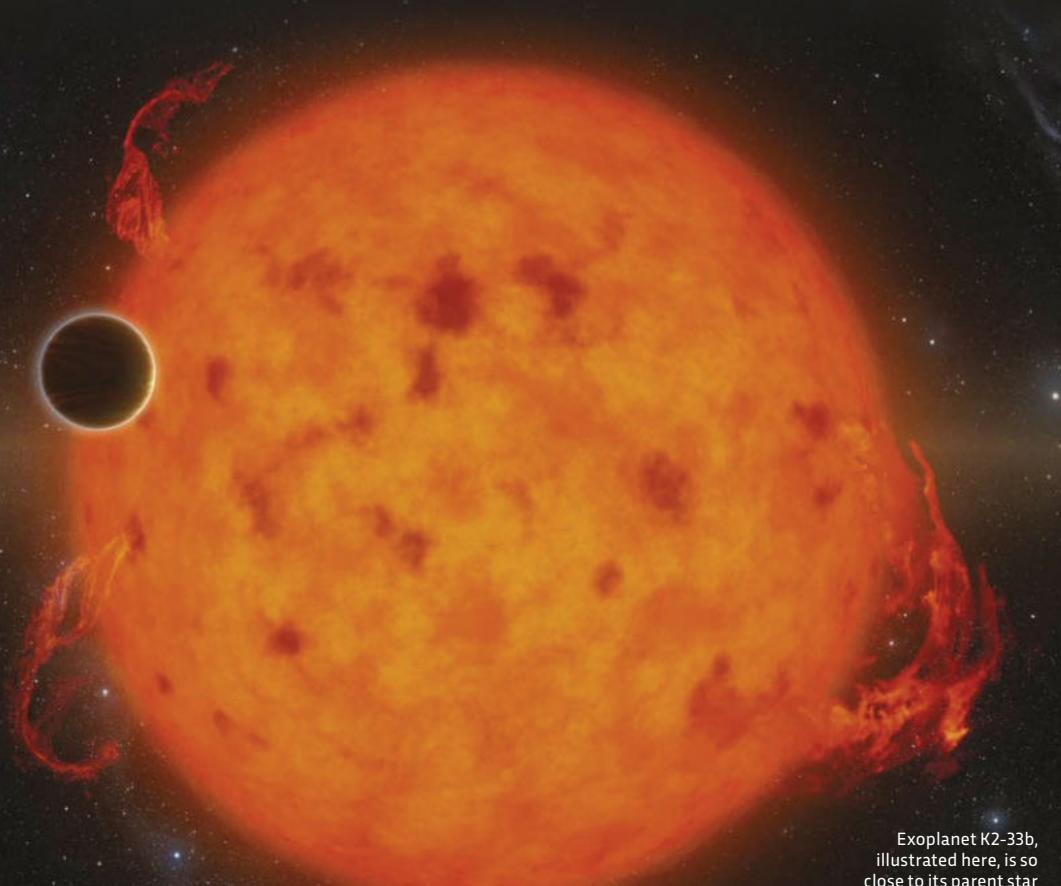
That may not sound very 'young', but bear in mind that Earth is 4.5 billion years old, and that the overwhelming majority of the 3,000-plus exoplanets discovered today are at least a billion years old. "Earth is a middle-aged planet – about 45 in human years," said lead author Trevor David. "By comparison, K2-33b would be an infant of only a few weeks old."

It is hoped that the new discovery will enable scientists to get a more accurate picture of how

planets are formed. Already, its proximity to its parent star – K2-33b is nearly 10 times closer to K2-33 than Mercury is to the Sun – has called into question our understanding of gas giants.

While such planets, which in our Solar System lie a long way from the Sun, have been found closely orbiting their parent stars before now, it was always assumed that they were formed further out then migrated inwards. K2-33b's relative youth, however, suggests it must have formed more or less where it is now.

K2-33b was first detected when Kepler's K2 mission picked up a slight, regular dimming of the light from its parent star, an observation that was later confirmed by the WM Keck Observatory in Hawaii.



Exoplanet K2-33b, illustrated here, is so close to its parent star that it takes just five days to orbit it

THE DOWNLOAD

Bramble Cay melomys

What's that? The latest herbal tea infusion?

Nope. It's a small rodent that lived on the island of Bramble Cay, off the coast of Queensland, Australia.

Tell me more.

It's thought to be the first known species of mammal to be wiped out by man-made climate change. The animals have not been seen since 2009 and have recently been declared extinct. It was considered the Great Barrier Reef's only endemic mammal.

How did that happen?

Bramble Cay measures just 150m by 340m and sits three metres above sea level. Experts say that rising sea levels due to climate change are to blame.

Are any others species at risk?

Yes. A recent study at the University of Connecticut has estimated that up to one in six species of animals and plants could go extinct if global temperatures rise by 4°C by the end of the century.



Goodbye, little friend

GENETICS

“By the time 10 years rolls around, the idea of writing a full human genome won’t be quite so daunting”

The Human Genome Project involved reading the sequence of letters in DNA. Scientists have now proposed writing DNA to make synthetic genomes. Lead researcher Prof Jef Boeke told us how they would be used

What is the 'Human Genome Project-Write' (HGP-Write)?

Just like Moore's Law, with the cost of circuitry and computing power dropping exponentially, there's been a drop in the cost of DNA sequencing – reading DNA – over the last 20 years. What we hope to do with this new HGP-Write project is to stimulate technology development, to increase the rate at which the price of writing DNA declines so that, by the time 10 years rolls around, the idea of writing a full human genome won't be quite so daunting.

You've made designer yeast genomes. How would you synthesise human DNA?

The technology for putting together short bits of DNA has been around since the early 1980s. Mature DNA is a double helix, but chemically you can synthesise 100 or maybe 200 mers [molecules made from DNA letters] in a single-stranded format. That's the starting material. We put them together into ever-bigger pieces, then insert those pieces right into the yeast cell. It's conceptually possible to do something similar with human cells.

Why create synthetic human genomes?

There's a lot we can do using model organisms like mice, worms, fruit flies and so on. I'd be perfectly happy if we simply worked in those arenas, but a lot of our science is funded by health-related agencies and they want to know what's going on in human cells. We could write thousands of human genomes and test them in cells and compare them to each other. All humans on the planet are different from one another, such as in disease susceptibility, so that's one important practical application. Another is that a lot of medicines are produced using mammalian cells. For example, the original polio vaccines, back in the 1960s, were



The original polio vaccine was infected with a virus. The HGP-Write project could allow scientists to create virus-resistant cells to make vaccines

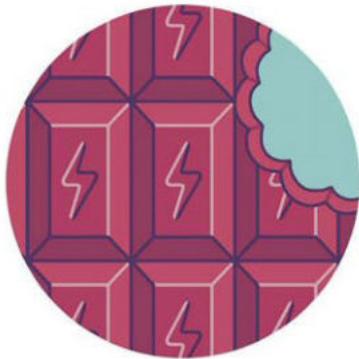


ABOVE: The cost of sequencing human DNA has reduced over the years, scientists now hope to reduce the costs of writing it too

actually made in monkey cells. Those monkey cell cultures were contaminated with a virus called SV40, which we now know can cause tumours. Thousands, if not millions, of people were injected with SV40, unbeknownst to them and everybody else until after the fact emerged. Luckily, no one's detected any cancer coming from SV40, but it could have been a disaster. If you had a cell line that was resistant to viruses, you wouldn't have to worry about that kind of scenario.

Some people worry about cloning humans from synthetic genomes. Is it really possible?

Yes, in principle. With the yeast project, we engaged an international community and made all the participants agree to a set of rules that we all believed in. By taking the lead on a project like HGP-Write, we can to some extent dictate terms like: "We all agree we are not trying to create a person here, we are doing this in cells, and that's it." You can manage the safety concerns and the social concerns. Before you go down a road of building something that's even mildly controversial, you engage with multiple stakeholders to try to identify those projects that are mutually interesting to members of the public and the scientific community.



CHOCOHOLICS

Physicists from Temple University have reduced the fat content of a Mars bar by more than 10 per cent by zapping the liquid chocolate with electricity. The effect is due to the cocoa solids clumping together.

HIGH-HEELS LOVERS

For fashionistas, nothing quite matches the elegance of a high-heeled shoe. The only problem is they aren't exactly comfy. Enter former SpaceX employee Dolly Singh who has designed a stiletto that offers more support and distributes weight more evenly. The downside: they cost £700.

GOOD MONTH

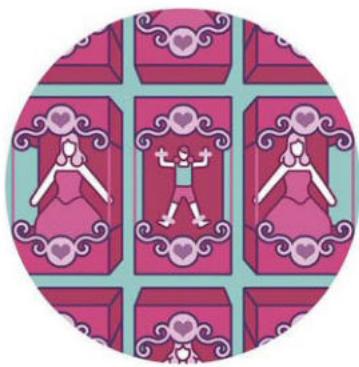
BAD MONTH

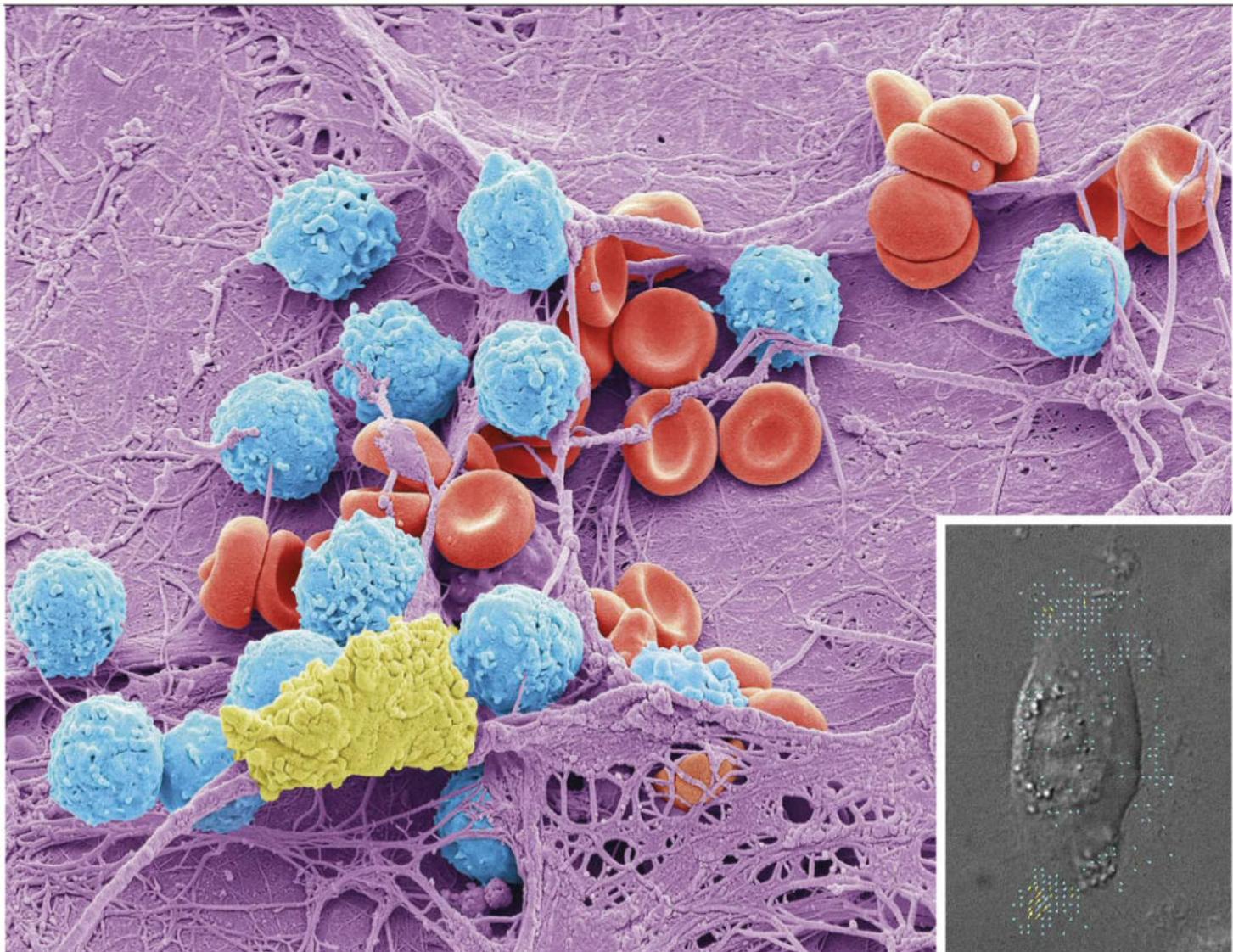
PIZZA LOVERS

The University of Surrey has found that the wood-burning ovens in São Paulo's 8,000 pizzerias burn over 300,000 tonnes of wood a year, pumping out carbon and other air pollutants.

DISNEY PRINCESS FANS

If your child is obsessed with Elsa, maybe encourage them to let it go. Brigham Young University found that kids who often play with Disney Princesses display more gender-stereotypical behaviour and are more likely to have body image issues.





HUMAN BODY

SKIN CELLS USE 'FEET' TO WALK TO WOUNDS

It seems your skin really can crawl, and you don't even have to look at icky pictures for it to happen.

Researchers at Washington State University have seen skin cells 'crawling' to a wound to repair it.

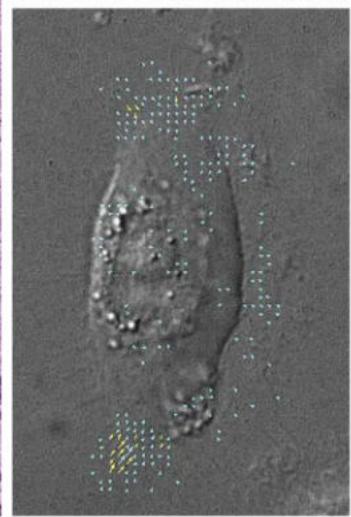
Under normal circumstances, skin cells are held in place because they are in contact with surrounding cells, while proteins bind them to the underlying connective tissue.

In the event of a wound, the team discovered that cells in the outermost layer of skin dissolve this protein glue, then reuse some of it to move to a wound site, then grow more cells to form new, healed skin. To achieve this, the individual cells crawl to the site of wounds by shuffling from side to side, using their outer edges as 'feet'.

INDIVIDUAL
CELLS CRAWL
TO THE SITE
OF WOUNDS,
USING THEIR
OUTER EDGES
AS 'FEET'

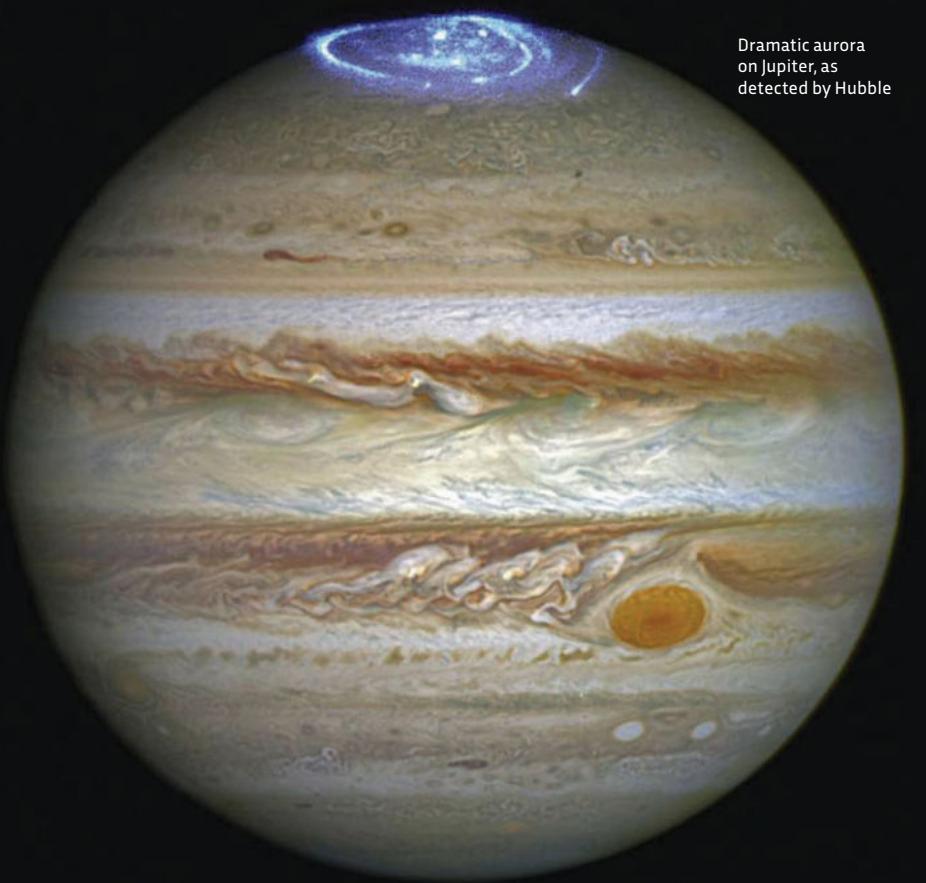
"It's using its internal muscle-related proteins to be able to generate these forces to allow the cell to use its feet and move along in step-wise fashion," said researcher Jonathan Jones.

With a better understanding of the process behind the cell movement, researchers hope they will be able to manipulate and enhance it to help wounds heal more quickly. "Wound healing is deficient as we get old and also among diabetics," said Jones. "That's why diabetics get skin ulcers. If we could work out a way to enhance the motility of these skin cells, we could promote healing in patients that have problems with wound closure and ulceration of the skin." To watch a video of the crawling skin cells, visit bit.ly/skin_crawl



MAIN IMAGE:
Skin wound showing red and white cells and platelets starting to accumulate

INSET IMAGE:
To mend a wound, skin cells will 'walk' towards it (the arrows in this image show movement)



JUPITER

Hubble captures stunning aurora in Jupiter's atmosphere

This spectacular image of Jupiter's aurora was taken using the ultraviolet capabilities of the NASA/ESA Hubble Space Telescope.

These striking light shows are created when high-energy particles speed into a planet's atmosphere near the magnetic poles and smash into atoms of gas, therefore knocking electrons off them. The ionised atoms then recombine with the freed electrons and give off light.

"These auroras are very dramatic and among the most active I have ever seen," said lead researcher Dr Jonathan Nichols from the University of Leicester.

Jupiter's auroras were first discovered by the Voyager 1 spacecraft in 1979, and were previously observed by Hubble in 2007.

The current programme aims to investigate how various components of Jupiter's auroras respond to different conditions in the solar wind, a stream of charged particles ejected from the Sun.

On Earth, the most spectacular auroras are caused by charged particles striking the upper atmosphere and exciting the gas molecules, causing them to glow red, green and purple.

Jupiter's auroras are much larger than those on Earth and are also hundreds of times more energetic because the giant planet's strong magnetic field pulls in vast amounts of charged particles thrown out by volcanoes on its orbiting moon Io.

Hubble scientists will continue to observe the auroras of Jupiter for several months.

Dramatic aurora on Jupiter, as detected by Hubble

THEY DID WHAT?!

Budgies taught grammar

What did they do?

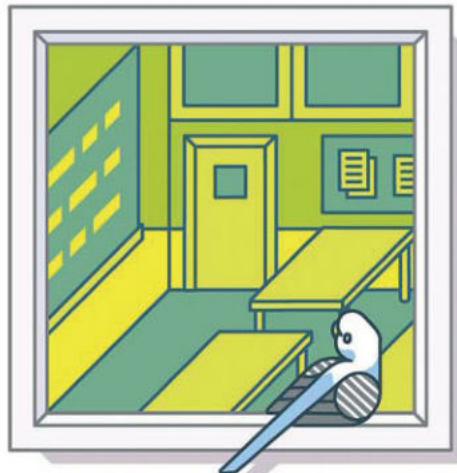
Scientists at Duke University taught budgies to understand basic grammatical patterns, an ability previously thought to be unique to humans.

Why did they do that?

The team played budgerigars patterns of sounds made up of three parts, with a structure of either XXY or XYX. Each time they heard XXY they were given a reward if they pecked a lever. If they pecked the lever at the wrong time, the light in their cage went out.

What did they find?

Not only were the birds able to identify the pattern at the correct time, they were also able to apply the rules to previously unheard sequences, suggesting they were able to learn basic grammatical rules.



"Do I know you
from somewhere?"



ZOOLOGY

FISH TAUGHT TO RECOGNISE HUMAN FACES

Call it 'plaice recognition' (get it?). A team at the University of Oxford has found that archerfish are able to recognise and remember human faces.

The researchers showed archerfish, a species of tropical fish known for shooting jets of water at its prey, two images of human faces and trained them to choose one by squirting it. The fish were then shown the familiar face alongside a series of 44 new, unknown faces and were coaxed into squirting one.

After two experiments, the fish proved to be more than 80 per cent accurate in their choices, even when more obvious details of the faces, such as colour and overall shape, were removed.

The result is surprising as fish lack the sophisticated visual cortex that allows humans to quickly distinguish different faces.

"Fish have a simpler brain than humans and entirely lack the section of the brain that humans use for recognising faces," explained lead researcher Dr Cait Newport. "The fact that archerfish can learn this task suggests that complicated brains are not necessarily needed to recognise human faces. Humans may have special facial recognition brain structures so that they can process a large number of faces very quickly or under a wide range of viewing conditions."

PHOTOS: CATHERINE HARRIS/SCIENCE PHOTO LIBRARY

**WHAT WE
LEARNED
THIS MONTH****SPRING COMES
EARLY TO CITIES**

Light from street lamps causes trees to start producing leaves up to a week earlier in cities than in rural areas, biologists from the University of Exeter have found.

**THE UNIVERSE IS
GETTING 'TIDIER'**

Images recorded using the Herschel space telescope have shown more and more cosmic dust is being mopped up thanks to the formation of stars.

**BUTTER ISN'T
UNHEALTHY**

A review of nine studies involving more than 600,000 people has found that butter is not linked to cardiovascular disease. Its bad reputation may be due to people spreading it on unhealthy foods such as white bread.

**WE GET OUR BEST
NIGHT'S SLEEP
ON TUESDAY**

Data from 5,000 Brits has shown that we sleep soundest on Tuesdays. It is thought the effect is due to alcohol and rich food, both of which can disturb sleep, typically being consumed later in the week.

HEALTH**Can cannabis be used
to treat Alzheimer's?**

Chemical compounds found in cannabis may help to fight the toxic proteins that build up in the brain in Alzheimer's disease, researchers at the Salk Institute in California have found.

The team found that tetrahydrocannabinol (THC), the psychoactive part of cannabis, can remove amyloid beta, a toxic protein that accumulates in the ageing brain and is considered to be a hallmark of Alzheimer's disease.

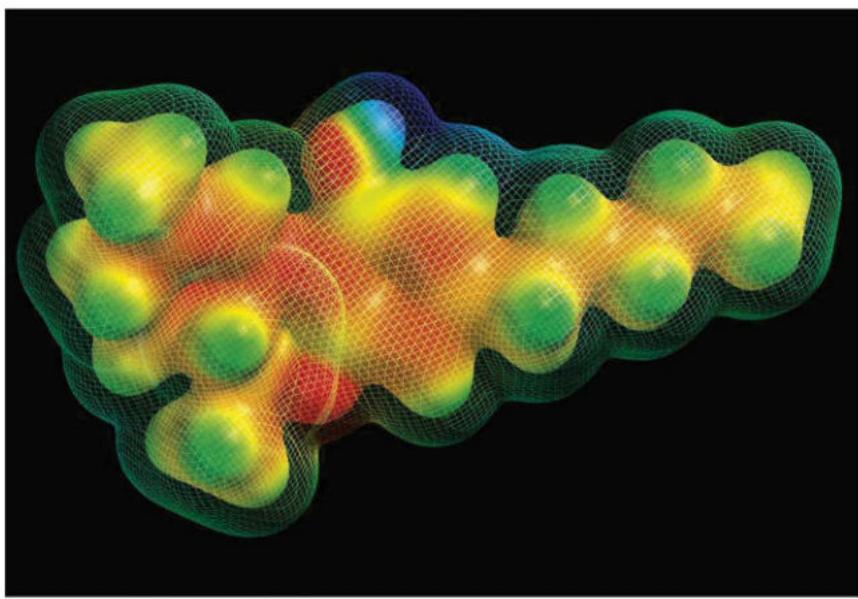
Exposing nerve cells to THC also shuts down the inflammatory response triggered by the presence of amyloid beta, a major component of the damage associated with Alzheimer's disease.

So far, the trials have only been conducted on neurons grown in the lab, but the finding could provide clues to developing novel therapeutics for the disorder, the researchers said.

"Although other studies have offered evidence that cannabinoids might be neuroprotective against the symptoms of Alzheimer's, we believe our study is the first to demonstrate that cannabinoids affect both inflammation and amyloid beta accumulation in nerve cells," said lead researcher David Schubert.

However, clinical trials on human subjects are required before any therapies using THC-like compounds can be developed.

BELOW: Computer model of THC, the psychoactive molecule present in cannabis. Cannabis is a class B drug in the UK, with a maximum sentence of 14 years for supply



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INNOVATIONS

PREPARE YOURSELF FOR TOMORROW

AUGUST 2016

EDITED BY RUSSELL DEEKS

RINGING THE CHANGES

Identikit smartphones are dead. Long live the anti-smartphone...

The smartphone recipe has barely changed over the last few years. Although every new handset has an extra pinch of megapixels and an added dash of processors, the formula has remained the same. But now, it seems the world's best tech chefs are cooking up a handheld revolution designed to get tech-lovers marvelling at their smartphones again.

Take the new Moto Z phones from Motorola. Both the Moto Z and Moto Z Force feature a 16-pin connector on the back that lets you attach your choice of 'mods', such as a projector, speaker or battery pack. Google, meanwhile, has announced that its own *fully* modular smartphone, Project Ara, will be available to consumers next year.

Then there's the Phab2 Pro from Lenovo. This 6.4-inch smartphone is the first to have Google's Tango ⚡

The Sirin Solarin has been dubbed the most secure smartphone – but peace of mind comes with a hefty price tag



Moto Z (left) lets you add your choice of mods, while Lumigon (right) comes with night vision

• augmented reality (AR) platform built in, enabling all kinds of new uses for your phone such as finding your way around a museum or 'test driving' new wallpaper before you buy. Lenovo says it believes AR will soon be as ubiquitous as GPS, and with the Phab2 Pro it's putting its money where its mouth is.

As well as its Phab2 Pro, Lenovo has been showing off a prototype bendy smartphone that can be worn like a wristband. This is an idea which Samsung has also been researching, and it looks like Samsung may be first to market, with its 'Project Valley' bendy phones expected to launch in 2017.

The UnaPhone Zenith, meanwhile, is about as inflexible as you can get: it's an Android phone that doesn't let you install any apps, not even Google's own. The idea is to prevent your phone getting infected by malware. But Unaphone isn't the only manufacturer concentrating on security features. The Sirin Solarin is billed as the world's most secure smartphone, with

end-to-end encryption of all calls and messages. The catch is you'll have to pay £9,500 to get one.

And that's not to mention the folding smartphone prototype recently shown off by China's Oppo; the T3 phone from Denmark's Lumigon that has built-in night vision; or Samsung's Galaxy S7, which is being touted as its toughest phone to date. All these innovations suggest that manufacturers know they can no longer rely on screen resolution or apps to shift their phones.

Deputy editor of *What Mobile* Thomas Wellburn agrees. "I think what we're seeing is manufacturers going towards driving the hardware itself forward, and at the lowest possible cost," he says. "The influx of smaller Chinese manufacturers, and in particular the arrival of the OnePlus 3, a fully fledged smartphone for just over £300, has really shaken up the market."

So while new smartphones will continue to come thick and fast, expect to see a lot more variety on offer in the near future.

“THE INFLUX OF SMALLER CHINESE MANUFACTURERS... HAS REALLY SHAKEN UP THE MARKET”

NEWS BYTES



IN THE PINK

Pregnant women in South Korea are being given portable Bluetooth sensors that cause a pink light in train carriages to illuminate when they board, encouraging other passengers to offer them a seat.

NOT SO BREEZY

Hugh McNeal, head of RenewableUK (formerly the British Wind Energy Association), has said there isn't enough wind in England to power any more turbines. Offshore wind farms, however, remain a viable option.

MOVIES ON THE MOVE

Virgin Trains is introducing its own Netflix-like streaming service called BEAM, which will enable passengers on its intercity services to watch films and TV, play games and read eBooks.



EYES DOWN

Busy junctions in Sydney, Australia are being fitted with traffic lights in the ground. The aim is to catch the attention of pedestrians engrossed by their phones and so, hopefully, reduce fatalities.

SOCIAL JUSTICE

A prolific car thief in Birmingham has been jailed for 17 years after Facebook suggested him as a friend to one of his recent victims, who recognised him and promptly contacted the police.

JC Sheitan Tenet's steampunk-inspired prosthetic arm doubles up as a tattoo machine



PROSTHETICS

Prosthesis envy

The field of prosthetics has seen some incredible advances in recent years. In late 2015, for instance, US research agency DARPA built an artificial arm that, through the use of carbon nanotube sensors, gives the wearer a rudimentary sense of touch. So are we reaching a point where having a prosthesis may, to some people, be preferable than having a flesh-and-blood limb?

That was the question discussed recently at a symposium in London entitled Prosthetics Envy. Already, organisers Virtual Futures point out, "some amputees are opting to have their artificial limbs upgraded with additional functions (such as a phone charger) or with aesthetic

enhancements (such as LED lights). Such embellishments reframe these devices as fashion statements." To get from there to people having limbs removed voluntarily is a bit of a leap – but then we live in a world where having your face injected with the botulinum toxin to reduce wrinkles is commonplace, and that would have sounded outlandish 20 years ago.

Just this month, prosthetics manufacturer Open Bionics revealed an artificial arm inspired by the game *Deus Ex*, while French tattoo artist JC Sheitan Tenet, who lost his inking arm in an accident, has fitted a prosthetic replacement that he says is better than the real thing. A cyborg future may be closer than we realise.

PHOTO: KWON SUNG-HOON/BUSAN METROPOLITAN CITY, SWA/THOMAS HOSEMAN



GAMING

PlayStation VR is coming

The E3 games show in Los Angeles in June saw Sony finally announce a release date for the hotly anticipated PlayStation VR. The headset, which is compatible with PlayStation 4 and the putative PlayStation 4.5, will cost £350 and be available in the UK from 13 October. The black-and-white headset contains twin 960 x 1,080-pixel displays (slightly lower-res than rivals HTC Vive and Oculus Rift), and has a 90° field of view.

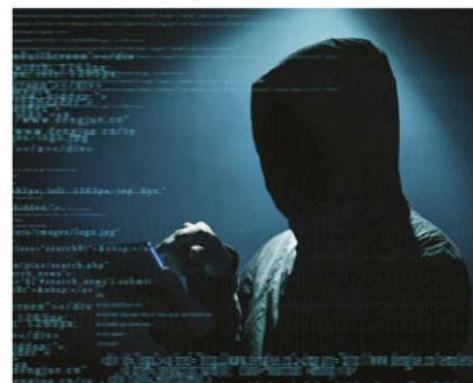
What's more, over 50 titles have already been announced for the system, including *Tekken*, *Star Wars*, *Final Fantasy* and *Gran Turismo* as well as a host of indie titles – not to mention more esoteric games such as *Job Simulator*.

SECURITY

The internet of spies

It seems those sceptical of the benefits of the Internet of Things (IoT) may have a point. At the Defense One Tech Summit on 10 June, the NSA's deputy director Richard Ledgett spoke about people installing camera- and microphone-equipped devices in their homes, telling reporters: "The first time you update the software, you introduce vulnerabilities... it's a good place to be in, from a penetration point of view." However, he added that they are only looking at it theoretically at the moment, as there are easier ways to keep tabs on terrorists than sneaking into their IoT devices.

Ledgett's remarks follow similar comments made by James Clapper, the USA's director of national intelligence, at a Senate hearing in February.





WANTED!

TWO WHEELS GOOD

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This bike is theft-proof, according to its manufacturers. It comes in three- or eight-speed versions and has a cycling computer and GPS system built into the frame, which means not only can you track your mileage, speed and so on, but should a light-footed thief make off with it, you'll know exactly where it is. Vanmoof has so much confidence in this working that, if for any reason you *don't* get your stolen bike back, they'll replace it free of charge.

From £840, vanmoof.com

JOG ON

SAMSUNG GEAR ICONX



Not keen on wearing a fitness tracker around your wrist? Then stick one in your ears! Samsung's new Gear IconX is a pair of wireless earbuds that will not only play music while you're out jogging, but also monitor your mileage, running speed and heart rate. There are play, skip and rewind controls on the buds themselves, which also feature a whopping 4GB of internal memory to minimise audio drop-out, though battery life is a mere 1.5 hours when using all of the features.

\$199 (£140 approx), samsung.com

PORTABLE PORTS

MOFLY MARBLE

If you've recently bought an Apple MacBook, Samsung TabPro, Huawei MateBook or any other gizmo whose makers have bafflingly equipped it with a solitary USB-C port, then like many users you may have found the lack of connectivity frustrating. Help is at hand,

though, in the form of Marble, a pocket-sized hub/docking station that gives you HDMI, DisplayPort and MicroSD ports, as well as four USB ports and four charging outputs. And, naturally, it will still charge your primary device as well.

\$175 (£120 approx), marbledcs.com



ROBOBUDDY

ASUS ZENBO

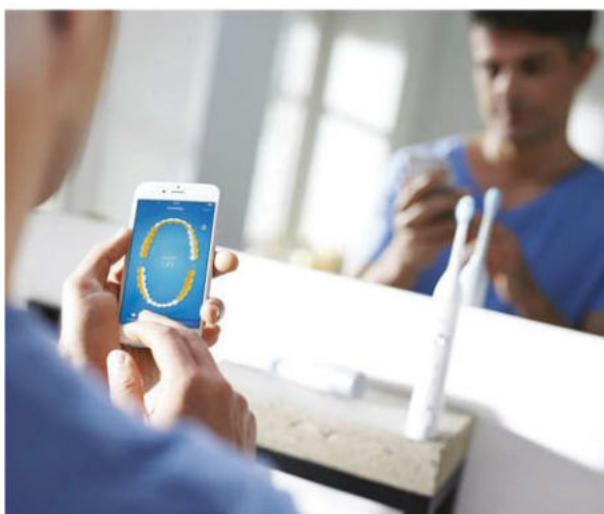
Debuted at the Computex show in Taipei in early June, Zenbo is a metre-high robot companion that runs on wheels, and whose 'face' is a touchscreen. It's equipped with a camera, depth sensor and AI for face recognition and navigation, and is said to have the 'personality' of a five-year-old child. It can be used to control smart devices, responds to voice commands, and even features a fall detection system that, in the event of an elderly owner (wearing the right wristband) taking a tumble, will automatically launch a video call to a designated person.

\$599 (£415 approx), zenbo.asus.com



BRUSH UP

PHILIPS SONICARE FLEXCARE PLATINUM CONNECTED



Electric toothbrushes are getting smarter. Philips' latest addition to its Sonicare range, the FlexCare Platinum Connected, is equipped with sensors that monitor your brushing and relay that information via Bluetooth (how else?) to an accompanying smartphone app called 3D Mouth Map, helping you identify areas that will need more attention if you want to avoid the dentist's drill. It features three pressure settings and a timer, and comes complete with a UV sanitising kit.

\$200 (£140 approx), sonicare.com

PRESS 'N' PLAY

SYNAPTICS TURNKEY USB

Equip your laptop with state-of-the-art biometric security, using this diminutive dongle from Synaptics. The device is a tiny fingerprint sensor that plugs into a USB port and is used to unlock your machine instead of the usual password, although password-based authentication will still be possible if you misplace the dongle. It's compatible with devices running Windows 10 and Microsoft Passport, and with the widely used FIDO (Fast IDentity Online) security system.

ETBC, synaptics.com



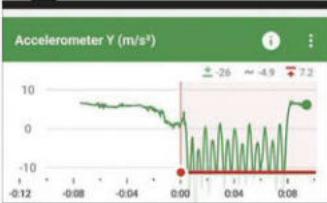
APP FEED



Science Journal

This research-friendly Google app helps you organise, collate and annotate data from your Android phone's internal sensors, or any bolt-ons you've added.

Free, Android



PlantNet

Gardeners and amateur botanists alike will love this app, which enables you to identify over 40,000 species of plant simply by pointing your phone's camera at them.

Free, iOS/Android



Pry

This game for iPhone and iPad seeks to recreate the troubling experience of living with post-traumatic stress disorder, as you toggle between 'real' and inner worlds.

£2.99, iOS



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MESSAGE OF THE MONTH

Resistance is futile

I always read Helen's articles with interest but I confess that in this instance I am puzzled. It is a fact that in a vacuum all objects fall at the same speed, regardless of size and weight. However, when air and wind are involved, the rate of descent can be influenced by size, but the pull of gravity will always be constant.

Helen states that the bigger the drop, the faster the terminal velocity. Although I can accept that very small droplets will be blown about by the wind, there are other factors.

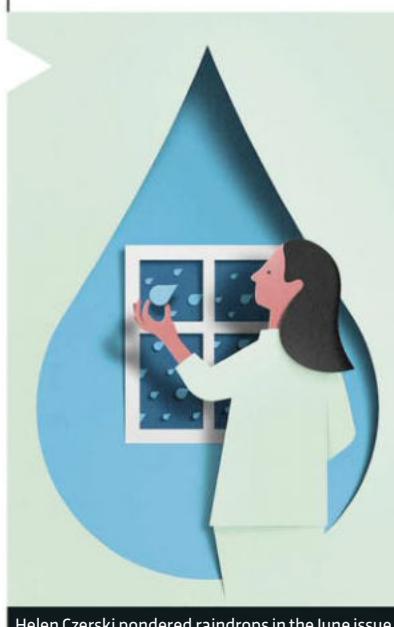
A larger drop will have to displace more air, and that resistance will slow it down. A smaller but still significant drop will have less resistance. Both drops will be affected by wind, so to say that the larger drop falls at a higher speed seems to me to be an assumption without merit.

Am I missing something? And if so, please could Helen elaborate?

Ron Seymour, Stevenage

When in a vacuum, all objects do indeed fall at the same speed because the gravitational pull per unit mass is the same for every size of object. But here on Earth, air gets in the way. Roughly speaking, the air resistance is related to the cross-sectional area of a falling object. A larger object experiences less air resistance per unit mass because it has a lower ratio of area to volume. So when a series of objects are the same shape, the larger ones will always have a higher terminal velocity. The biologist J.B. S. Haldane wrote a fantastic essay on this back in 1926 called 'On being the right size', and I highly recommend reading it.

— Dr Helen Czerski, BBC Focus columnist



Helen Czerski pondered raindrops in the June issue

Power to the people

In response to David Clubb's letter in the July issue, I should like to make the following points. The UK's Department of Energy and Climate Change has a target of generating electricity from the following sources by 2035: 50 per cent from renewable sources, 35 per cent from nuclear and 15 per cent from gas-fired power stations.

This is probably a very optimistic target, but confirms its faith in renewable sources and



We hope to obtain 50 per cent of energy from renewables

Charles Scott, Edinburgh

Hi Charles, I think that both nuclear power and high-tech energy storage solutions will play vital roles in providing affordable energy. — Ed

WRITE IN AND WIN!

The writer of next issue's Message Of The Month wins a Belkin 6600 metallic power pack, worth £49.99. This light and sleek-looking charger lets you juice up two devices while on the go, making it perfect for holidays and day trips this summer. belkin.com



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nuclear power. It is important that we continue to investigate the many sources of power available to ensure a reliable and cost-effective electricity supply. At present it is almost impossible to establish the true cost of electricity to consumers because of the subsidies, guaranteed prices and government interference in the market.

Electricity storage may be dropping in price but it is always going to be more expensive than the original generation cost. The editor's comment that energy storage "is rapidly dropping in cost, hastening the obsolescence of nuclear energy..." is a sweeping statement which in my view is impossible to provide factual evidence to justify. There are many countries investing in nuclear energy, the latest is Sweden who are investing approx £33bn to provide 8.4GW nuclear replacement plants.

The many new developments that are taking place in nuclear research and development lead me to believe that nuclear energy will be with us for many years to come, although I still support electricity generation from renewables as part of our energy mix.

Charles Scott, Edinburgh

Mercury rising

I'm a big fan of your astronomy features and of the magazine in general. So when I read Stephen Baxter's article about our future on Mercury (May), I had to ask myself why the use of ISRU (in-situ resource utilisation) and the creation of mining bases on Mercury – instead of on the Moon – was prioritised.

Helium-3 is a material that I consider to be of crucial importance, and it is abundant on the Moon. From the regolith that is extracted for helium-3, we can obtain other useful metals like aluminium. If we leave aside that fact for a moment, one of the problems we will have to face on Earth in the near future is the energy crisis. If we listen to the forecasts, we will be able to eventually create energy through fusion reactors, which will need helium-3 to run.

Ma José, email

Indeed, the Moon is likely to be the proving ground for our expeditions to other planets in the Solar System. In the longer term, it will probably be a target for colonisation. We simply chose to look further forward to mark the transit of Mercury in May. – **Ed**

We should concentrate on colonising and exploring the Moon rather than Mercury (pictured), says Ma José

Live long and prosper

Mr Trousdale's letter in the June issue raises the question of the importance of one individual over a group. He argued that one talented 20-year-old soccer player is more important than a group of pensioners. It is trite of me to raise the issue of 'the needs of the many outweigh the needs of the few' (Spock's logic in *The Wrath Of Khan*). Plus, the utility of an individual does not end when they get old. What if the larger group were Nobel laureates? What if the individual was a murderer?

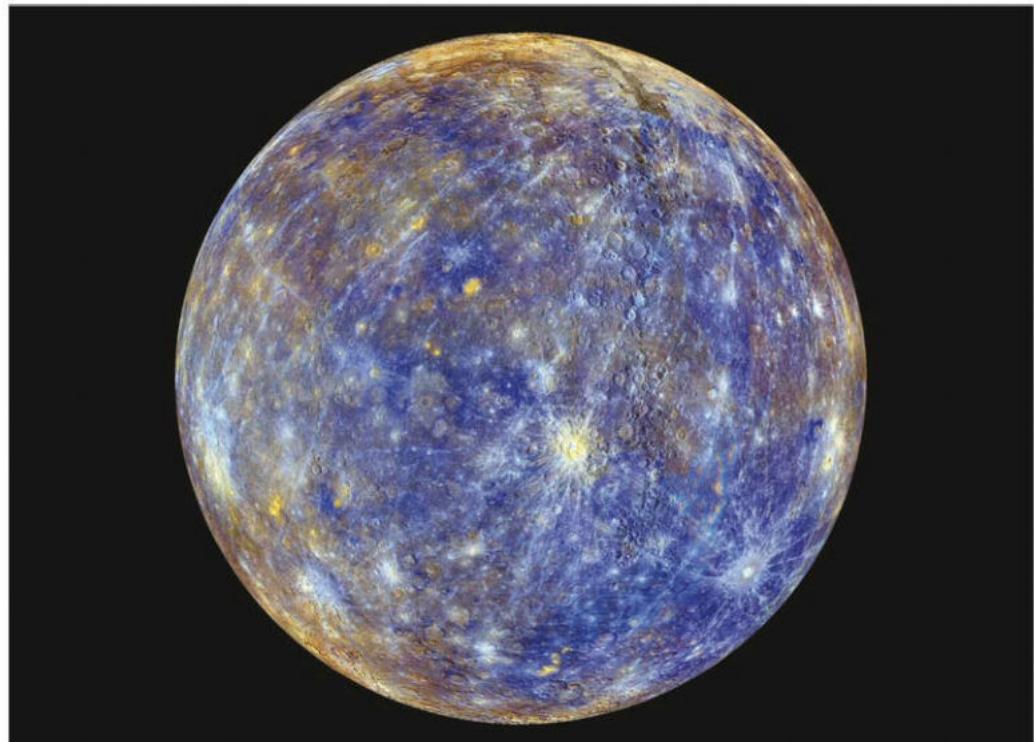
People will make the choice using their emotions, and will justify it using an implied logical argument. Not everyone will come to the same conclusion, such is the joy of an ethical argument.

Dan Taylor, Sussex

OOPS!

In the July edition it was wrongly quoted that sharks are aquatic mammals. Sharks are, of course, fish. We have thrown our news editor into the nearest body of shark-infested water to take some notes.

In the June issue (p27), we incorrectly named researcher Zhe Xu as Zhe Hu.



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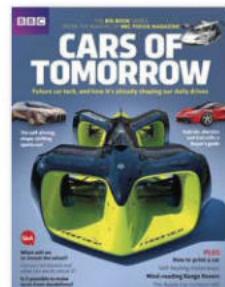
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Alphr, February 2016

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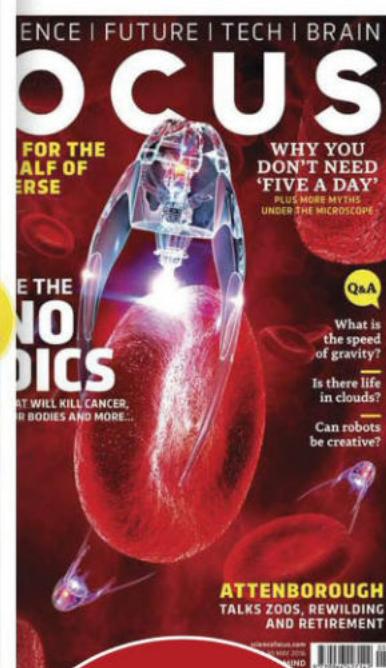
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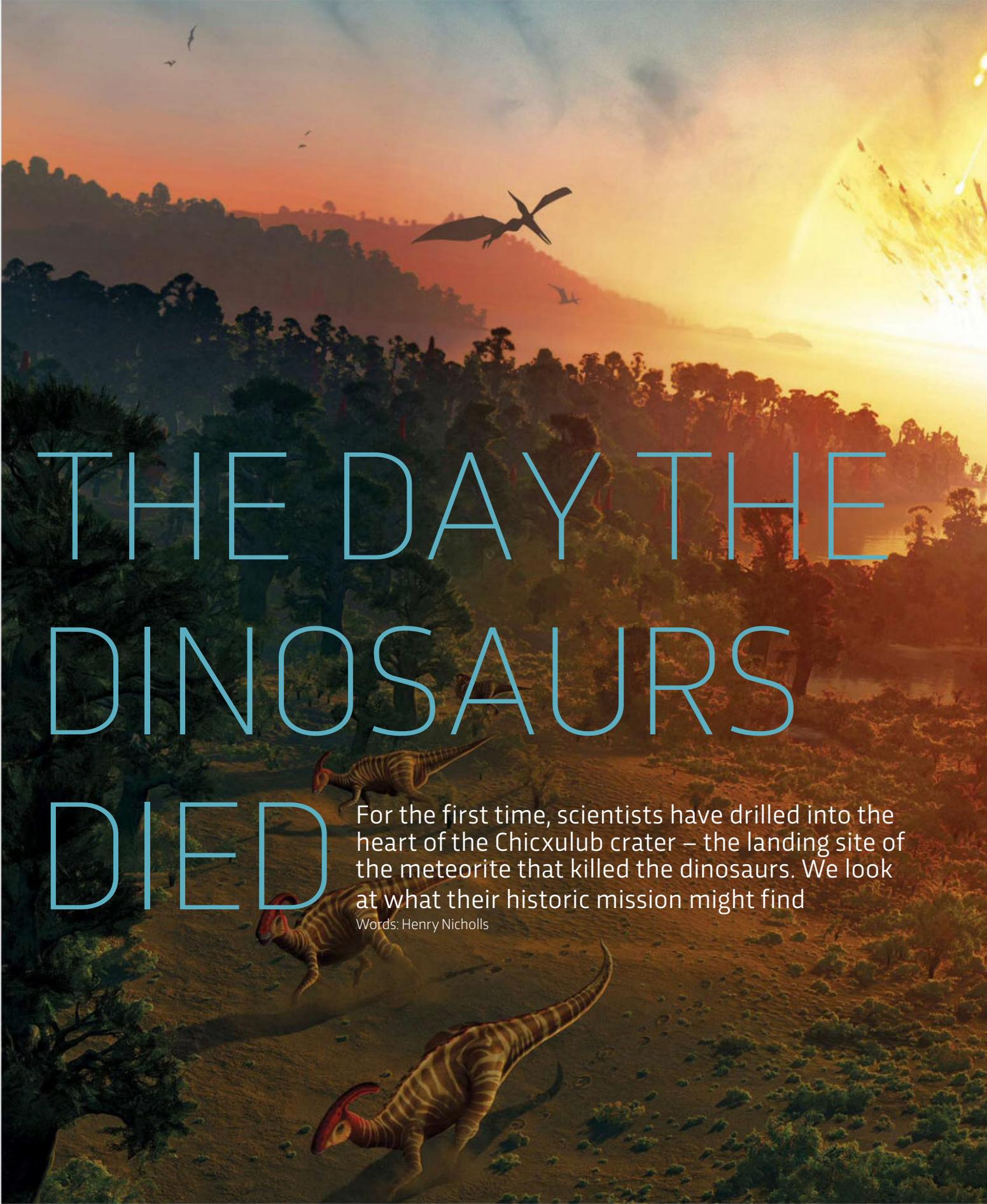
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A wide-angle, high-angle shot of a prehistoric landscape at sunset. The sky is filled with warm orange and yellow hues, with a large, bright sun partially visible on the right. In the foreground, a large, striped, long-necked dinosaur (resembling a Brachiosaurus) walks across a dry, brownish field. Behind it, another smaller dinosaur with a prominent red horn on its head (resembling a Parasaurolophus) walks away. In the middle ground, a pterosaur with long, thin wings is captured in flight against the sunset. The background is a dense, dark forest of coniferous trees on a hillside, with a few small birds flying in the sky.

THE DAY THE DINOSAURS DIED

For the first time, scientists have drilled into the heart of the Chicxulub crater – the landing site of the meteorite that killed the dinosaurs. We look at what their historic mission might find

Words: Henry Nicholls



The meteorite left a crater 200km across when it smashed into the planet. Today, this geological scar lies buried beneath the Yucatán Peninsula

C

ore 40. To the untrained eye, this three-metre section of rock winched up from a borehole beneath the Gulf of Mexico might not look like much. But for Sean Gulick, a geologist at the University of Texas at Austin, it's a sample that holds secrets about one of the most catastrophic events in the history of planet Earth.

For Gulick, the core will tell him the story of the day the Earth shook. Sixty-six million years ago, a 14km-wide meteorite slammed into our planet. Wildfires raged, earthquakes rumbled, and a dusty curtain fell upon the Earth. It was the beginning of the end for around 75 per cent of the planet's species, including all non-avian dinosaurs.

Travelling at 20km per second when it entered Earth's atmosphere, the meteorite left a crater 200km across when it smashed into the planet. Today, this geological scar lies buried beneath the Yucatán Peninsula in southeastern Mexico – and now, for the first time, we've drilled into its heart.

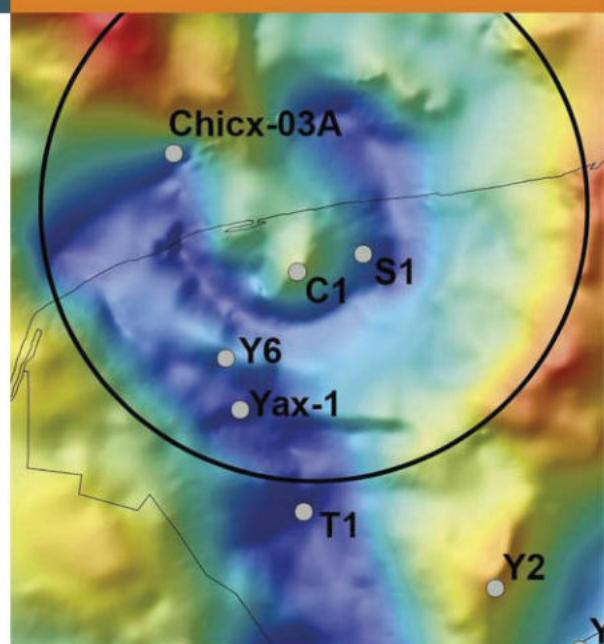
Throughout April and May, Gulick was stationed on a drilling rig just off the Yucatán Peninsula. He's the co-chief scientist on Expedition 364, the joint project by International Continental Drilling Program and the International Ocean Discovery Program to drill down into the Chicxulub impact crater. On this boat-cum-drilling platform, 30km off the Mexican coast, his team have worked day and night to bore down to over 1.3km beneath the seabed to extract precious cores of rock.

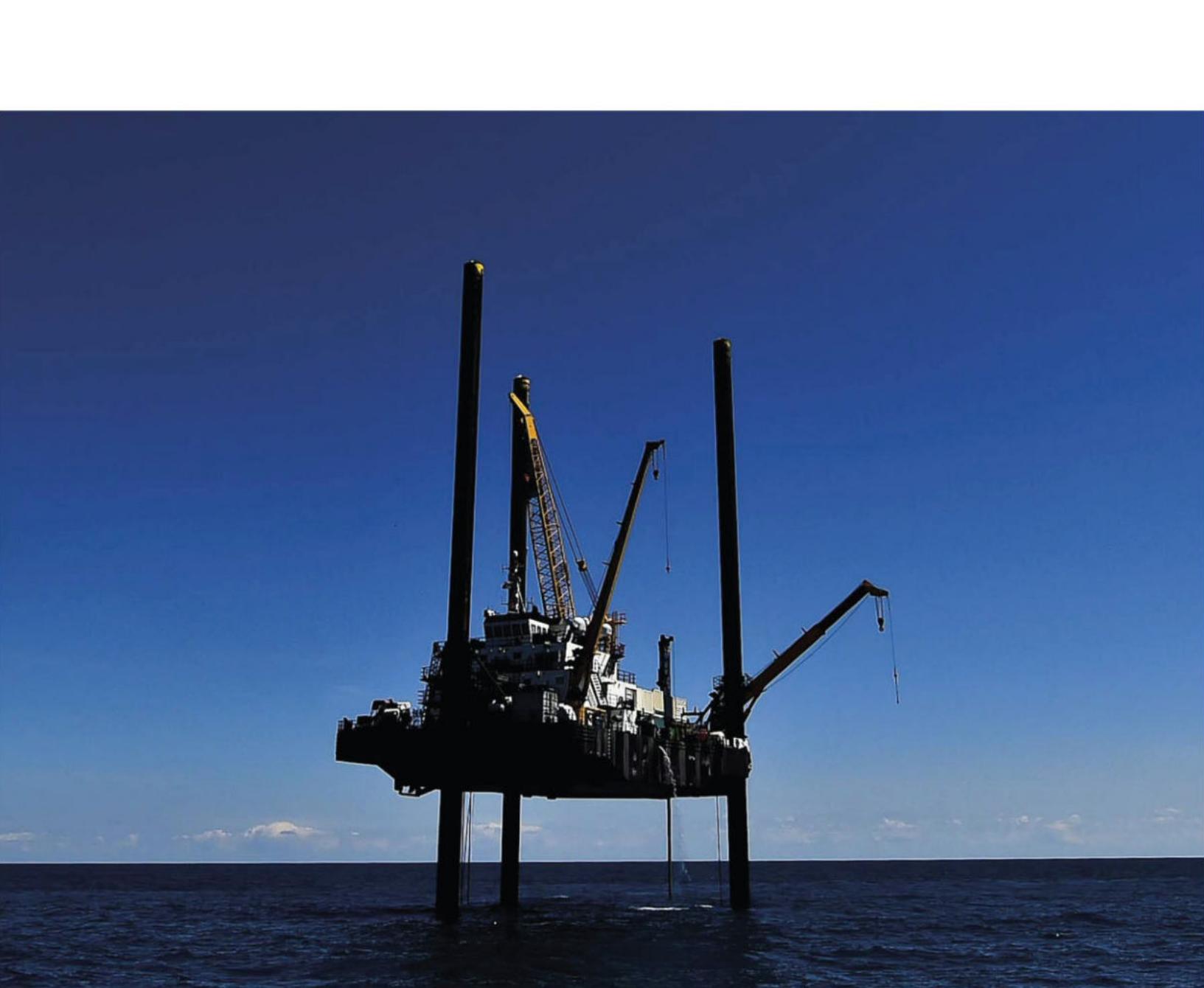
When these cores are cracked open in September, geologists, physicists, chemists and biologists will be racing to find out what happened in the minutes, hours, days and years after touchdown. What they find could help us to

THE STORY OF THE CRATER

In the late 1970s, the Mexican oil company Pemex was scouring the Gulf of Mexico for possible sites to drill. A ring of mountains on the ocean floor with a diameter of around 70km sparked the interest of Pemex geologist Glen Penfield. Further scrutiny of the Yucatán Peninsula revealed another concentric ring, strongly suggesting some kind of catastrophic impact, with its centre lying close to what is now the small coastal town of Chicxulub.

When a young University of Arizona graduate called Alan Hildebrand got in touch with Penfield, they teamed up and tracked down cores from three deep exploration wells that Pemex had drilled within the region (C1, S1 and Y6 in the gravity map below). In these rocks, they found evidence of a cataclysmic event at precisely the moment the dinosaurs vanished, at the end of the Cretaceous Period. Now, 25 years on, we've drilled deeper into the crater than ever before (Chicx-03A below). All eyes will be on the expedition scientists in September when they begin analysis of the 1,300m-long core.





understand why this single rock had such lethal and far-reaching consequences across the entire planet, but also how life was able to recover following the impact.

INTO THE IMPACT

Core 40 is of interest because this section may help explain how one asteroid (or comet) could have had such global consequences. Up to this point, the team had pulled out 39 cores of limestone all the way from 500m to 620m below the seabed. "Then suddenly we hit a layer with fragments in it," says Gulick.

They'd found the top of a thick blanket of 'breccia', a jumbled layer of the shattered, melted and traumatised debris that settled in the minutes or hours after impact. "I didn't expect it to be this nice, sharp transition from limestone, boom, right into angular material with melt in it," says Gulick.

Of particular interest are the microfossils that sit just above this breccia, which should paint a vivid



ABOVE: Expedition 364 set up a scientific platform in the ocean and spent April and May drilling into the seabed to extract core samples from the Chicxulub impact crater

LEFT: A foraminifera fossil. These tiny creatures proliferated and diversified rapidly after the Chicxulub impact

CROSS-SECTION OF THE CRATER

0m
Seabed.

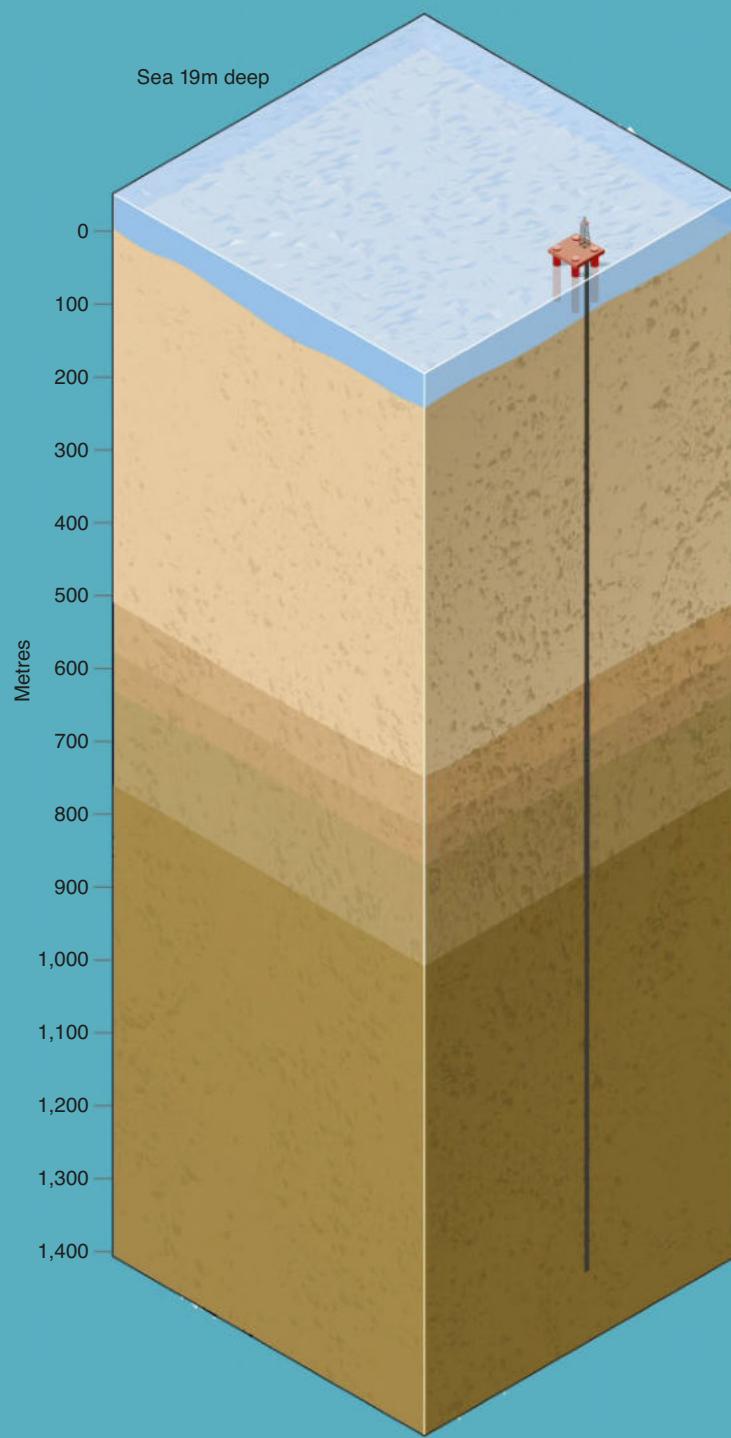
503m
Coring begins. As the focus of the expedition is on the impact crater, the scientists race through the first 500m of limestone before beginning to pull up cores of rock, 3m at a time.

550m
Algal blooms. Around 55 million years ago, some 10 million years after the asteroid impact, the Earth was around 5°C warmer than at present. Scientists are hoping to recover black shales, the geological remnants of carbon-rich algal blooms predicted to have thrived in the warmer conditions.

550-620m
Approaching ground zero. As the drill reaches the top of the impact layer, the ecology is expected to thin out to just a few, rather simple species. By studying the chemical make-up of the very first foraminifera to colonise the site after the impact, it should be possible to infer the local conditions at the time.

620-740m
The impact layer is a chaotic mix of fragmented rocks and melt that settled in the minutes and hours after the asteroid hit. It could contain microorganisms that took up residence in the aftermath to capitalise on the rich chemistry.

740-1,335m
The peak ring. By paying special attention to the age and sequence of rocks in the peak ring, geologists hope to solve the mystery of how these structures form. Satellite data indicates that the rock in the peak ring is not as dense as it might be. Are there cracks and fissures, and what kind of microbes might live in these voids?



TIMELINE

A planet in shock

Earth in the hours, years and millennia after the impact



HOURS

Huge earthquakes, megatsunamis up to 300m high, winds of over 1,000km/h and rampant wildfires result in instant annihilation for many species.



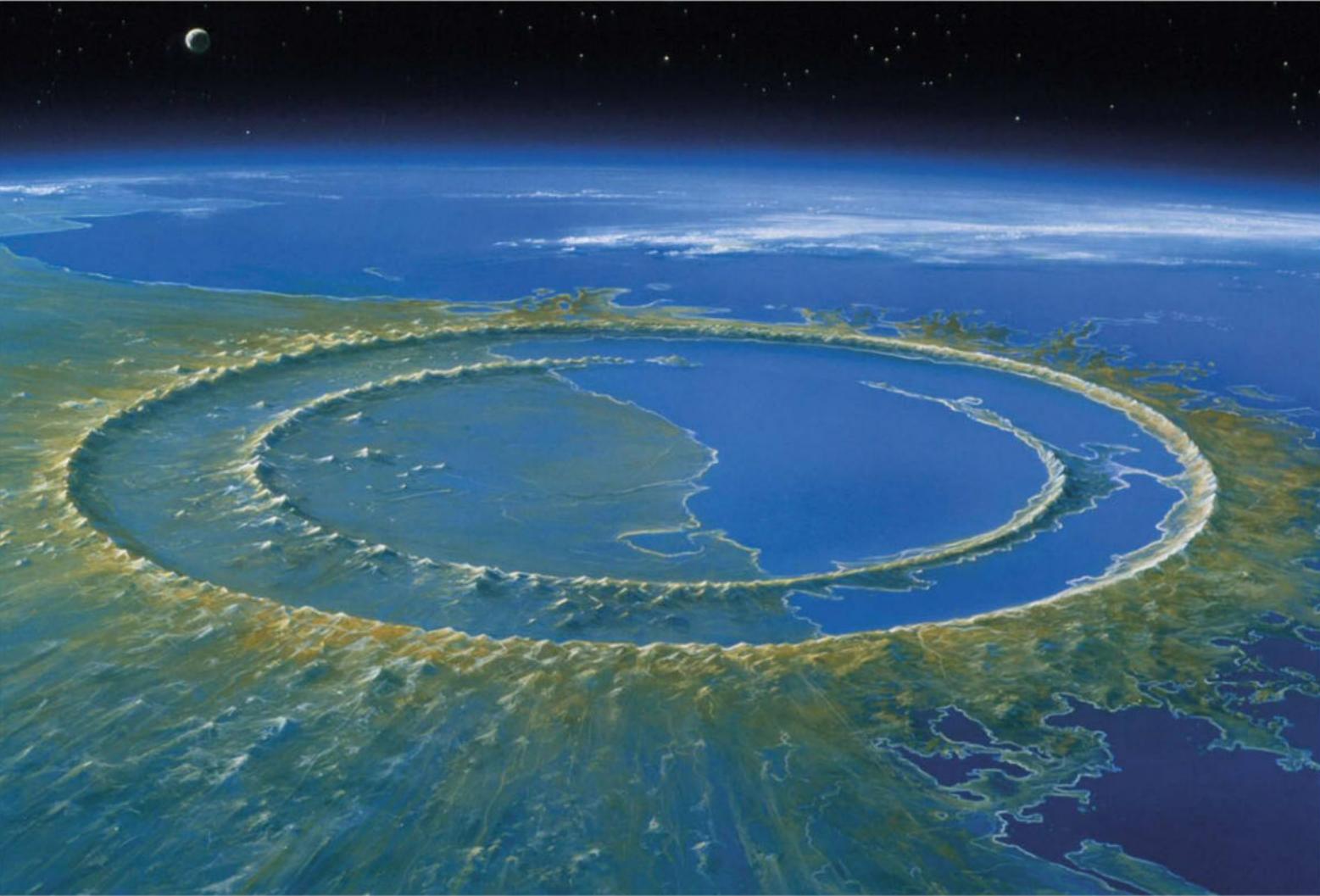
WEEKS

Dust from the impact and soot from wildfires block out sunlight for many years. Plants that survived the impact soon struggle. Food webs start to unravel.



YEARS

Prior to the impact, non-avian dinosaurs are already in decline, but the impact seals their fate. If any species survive the impact, it's not for long. Over 90 per cent of all mammal species also go extinct. The largest mammals are hardest hit; the survivors are all smaller than a cat. On land, forests and flowering plants struggle with the low light levels, resulting in a preponderance of species like ferns, algae and moss.



● picture of the local conditions in the immediate aftermath of the impact. One of those given the responsibility of studying these fossils is Chris Lowery, a post-doctoral fellow in palaeontology at the University of Texas at Austin.

“I’ve lain awake at night sometimes, wondering what we’ve got in core 40,” he enthuses. “This is the kind of thing I got into science to do. It’s so cool to be part of something like this.” Lowery’s expertise is in foraminifera, single-celled creatures that often boast beautifully complex internal shells or ‘tests’. By studying the chemical make-up of these fossilised structures, he hopes to be able to reconstruct the temperature, salinity and local productivity of the water that filled the crater, giving an insight into the kind of environment that survivors of the asteroid would have faced.

Based on work elsewhere, we know that the asteroid impact led to the extinction of more than 90

per cent of all floating, plankton-like foraminifera. The species that survived were typically small and generalist, but within a mere 100,000 years they had diversified into dozens of different species. “I’m very excited to see here at ground zero what the properties of the ocean were that might have driven that evolution,” says Lowery.

Meanwhile, analysis of the carbon isotopes in the rock core will help us to understand how the carbon cycle was affected by the impact. This in turn will tell us more about the response of the world’s ●

ABOVE: Artist’s impression of the Chicxulub crater shortly after impact. The inner ‘peak ring’ is where scientists are focusing their efforts today

“I’ve lain awake at night sometimes, wondering what we’ve got in core 40”



300,000 YEARS

Because mammals from several different groups survived, mammal diversity recovers quite quickly, soon doubling the number of species before the extinction.



1 MILLION YEARS

Deciduous trees, reliant on wind pollination, begin to return. Evergreens, which rely on insects and animals for reproduction, take longer to bounce back.



3 MILLION YEARS

In the oceans, there is a rapid flourishing of the plankton-like floating foraminifera. This contributes to the recovery of most marine systems.



10 MILLION YEARS

The surviving reptiles are quick to diversify, with the appearance of iguanas, monitor lizards and boas. Many insect lineages survive the impact. After the event, ants and termites increase in their diversity. Butterflies, too, spread their wings.



15 MILLION YEARS

In a few million years the ancestors of most modern birds undergo a rapid evolution into the multitude of lineages and thousands of species we see today.



TOP: A clump of breccia recovered from the impact crater

ABOVE: The drill site lies 30km off the coast of Mexico



plants to the event – and the dinosaurs that depended on them. Similar analysis has been carried out elsewhere, but the Chicxulub cores contain large amounts of material, so it should be possible to build up a more accurate, high-resolution picture of the events that led to a mass extinction.

LIFE DOWN BELOW?

There might even be signs of actual life in the rubble-like breccia and beneath – microorganisms that

"I was super stressed before I got on the platform. When the super gorgeous cores began to come out of the ground, the stress vanished"

have been living and evolving deep underground, far from the human eye, for many millions of years.

"Most of life on Earth is underground," says Charles Cockell, an astrobiologist at the University of Edinburgh. "Something like a massive asteroid impact that killed off the dinosaurs would also have dramatically disrupted the deep biosphere, particularly at the place of impact," he says. "But it may not necessarily have been all bad."

A decade ago, Cockell was part of a similar project in Chesapeake Bay in Virginia on the east coast of the United States, the site of a smaller and, at 35 million years old, more recent impact. This event appears to have fractured the underlying rock, improving the flow of water and creating a habitat that would have been particularly suited to microbial life, he says. "We found there was an increase in the numbers of microbes in impact-fractured rocks."

The same may have occurred at Chicxulub. "The breccia is almost like chicken soup for microbes,"



ABOVE: This tiny grain of 'shocked quartz' on the screen was taken from the impact crater – the dark dots running from its top left to its bottom right are deformations that occurred when the meteorite hit

ABOVE RIGHT: Checking equipment on the drilling platform

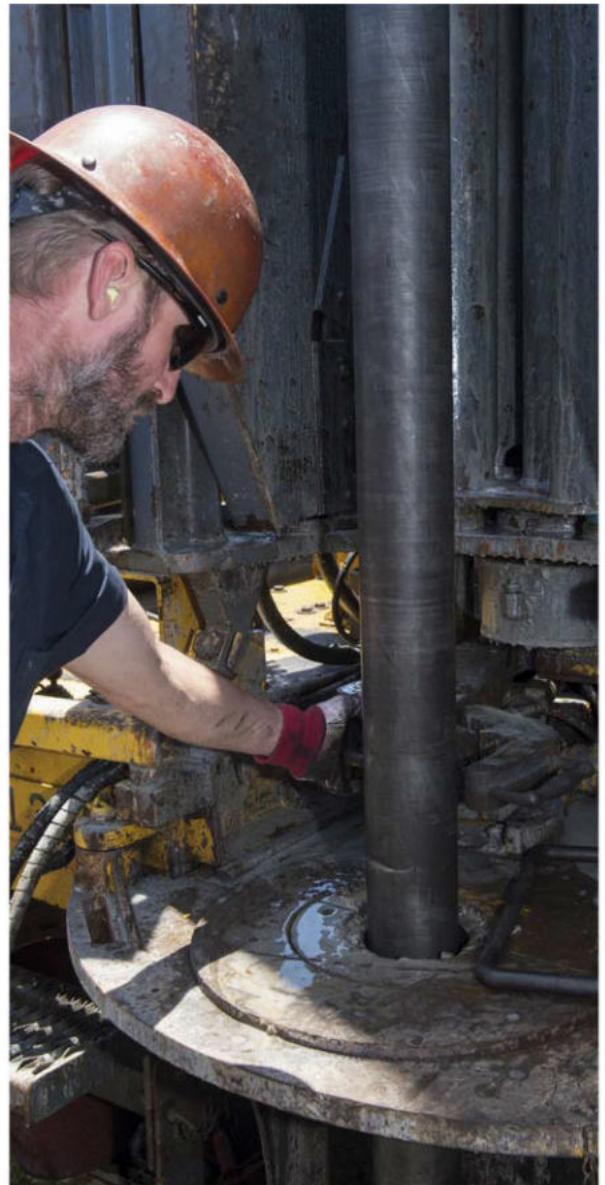
says Cockell. "It's got everything in it that's leaching out and providing food for microbes."

Further down, in the underlying granite, the trauma caused by the impact may have created opportunities for microorganisms. "At the immediate point of impact, everything would have been sterilised, so it was certainly bad for them in the same moment it was bad for the dinosaurs," he says. "But in the longer term, it will have improved conditions for life."

It's even possible that impact craters could have been suitable spots for the origin of life on Earth more than 3.5 billion years ago. The conditions at the time of the Chicxulub impact were "radically different" from those on the early Earth, says Cockell. But the microbial ecology under the Gulf of Mexico could hint at some of the biochemical challenges that the first life forms would have faced, he says.

CRATER CONUNDRUMS

In the days before drilling began, there was a lot of nervous excitement among the scientists involved.



"I was super stressed before I got on the platform," admits Joanna Morgan, a geophysicist at Imperial College London and co-chief scientist of the expedition along with Gulick. But as soon as the "super gorgeous" cores began to come out of the ground, the stress just vanished, adds Morgan.

That said, not everything went smoothly. Early on in the project, a 200m piece of piping fell to the bottom of the hole, putting a complete stop to drilling. "The whole thing was a good week of nail-biting before we actually got the first 50-million-year-old core just below that point," says Gulick.

But apart from this glitch, everything went pretty much to plan, with cores being pulled up to the surface 24 hours a day, seven days a week. "Sometimes we would succeed in coring 30m a day," says Gulick. When the money ran out and it was time to withdraw the drill at the end of May, the hole stretched for 1,335m below the seabed, just shy of the project goal of 1,500m. ➤



"It's the only well-preserved large impact on Earth, so we can test the fundamental ways that impact cratering affects a planet"

● The deeper cores will be of special interest to geologists like Gulick and Morgan, as they should help account for the formation of the so-called 'peak ring', a circular mountain range that lies within the crater, roughly midway between the centrepoint and the rim. According to Gulick, we can also see structures like this on the Moon, on Mercury and Mars, "but we haven't gone and gotten those rocks," he says.



WHAT REALLY KILLED THE DINOSAURS?

In 1980, Nobel Prize-winning physicist Luis Alvarez and his team discovered a thin layer of iridium blanketing Earth at precisely the moment when the dinosaurs disappeared from the fossil record. As iridium is one of the rarest elements in Earth's crust, but is found in asteroids in far higher concentrations, the scientists imagined vast quantities of dust (including extraterrestrial iridium) propelled high into the stratosphere and distributed worldwide.

"The resulting darkness would suppress photosynthesis," they wrote in *Science*, which would have led to the rapid collapse of food webs and the demise of the dinosaurs. A decade later, in 1990, geologists identified Chicxulub in the Gulf of Mexico as the most likely site of this impact.

Few scientists now dispute the terminal consequences of the Chicxulub event for many species, but there is also evidence to suggest that other factors could have been part of the dinosaurs' demise. The Deccan Traps, in what is now central India, are one of the largest volcanic features on Earth. There is some uncertainty over exactly when they formed – it could have been just before the asteroid impact or as a result of the aftershock – but the volcanic gases released would have had a chilling effect on the climate. It seems likely that the Chicxulub impact would also have triggered a wave of secondary events, like earthquakes, megatsunamis, wildfires, volcanism and acid rain, that could all have helped push Earth's reptilian rulers over the edge.

At Chicxulub, on the other hand, the scientists have drilled right into the peak ring. "It's the only well-preserved large impact on Earth, so we can test the fundamental ways that impact cratering affects a planet," he explains.

The prevailing model to explain this mountainous ring is that following the initial impact there was some kind of rebound of fractured rocks at the centre of the crater, which rippled outwards before

ABOVE: Dust from the impact cloaked the entire planet in darkness, leading to the widespread collapse of food webs

eventually coming to a stop. To picture this, think of what happens when you throw a stone into a pond.

Superficially, the rock in these deeper cores looks just like normal granite, says Morgan. "Except when you look closely, it's very highly fractured," she says. "It has a very strange set of physical properties. I think it's going to explain to us how rocks that are really hard are weakened enough to be able to move many, many kilometres during this impact event."

The cores, and all the valuable clues they contain, are on their way to Bremen in Germany, where the scientists will regroup in September to break them open and begin the analysis proper. It seems likely that each will be dealt with in sequence, from core 1 all the way through to core 303.

For scientists like Chris Lowery, who are eagerly waiting to delve into core 40 at the top of the impact layer, "cores 1 through 39 are going to be an exercise in patience". But if core 40 lives up to its promises, the wait will surely be worth it. 

Henry Nicholls is a science writer and author. He tweets from @WayOfThePanda.

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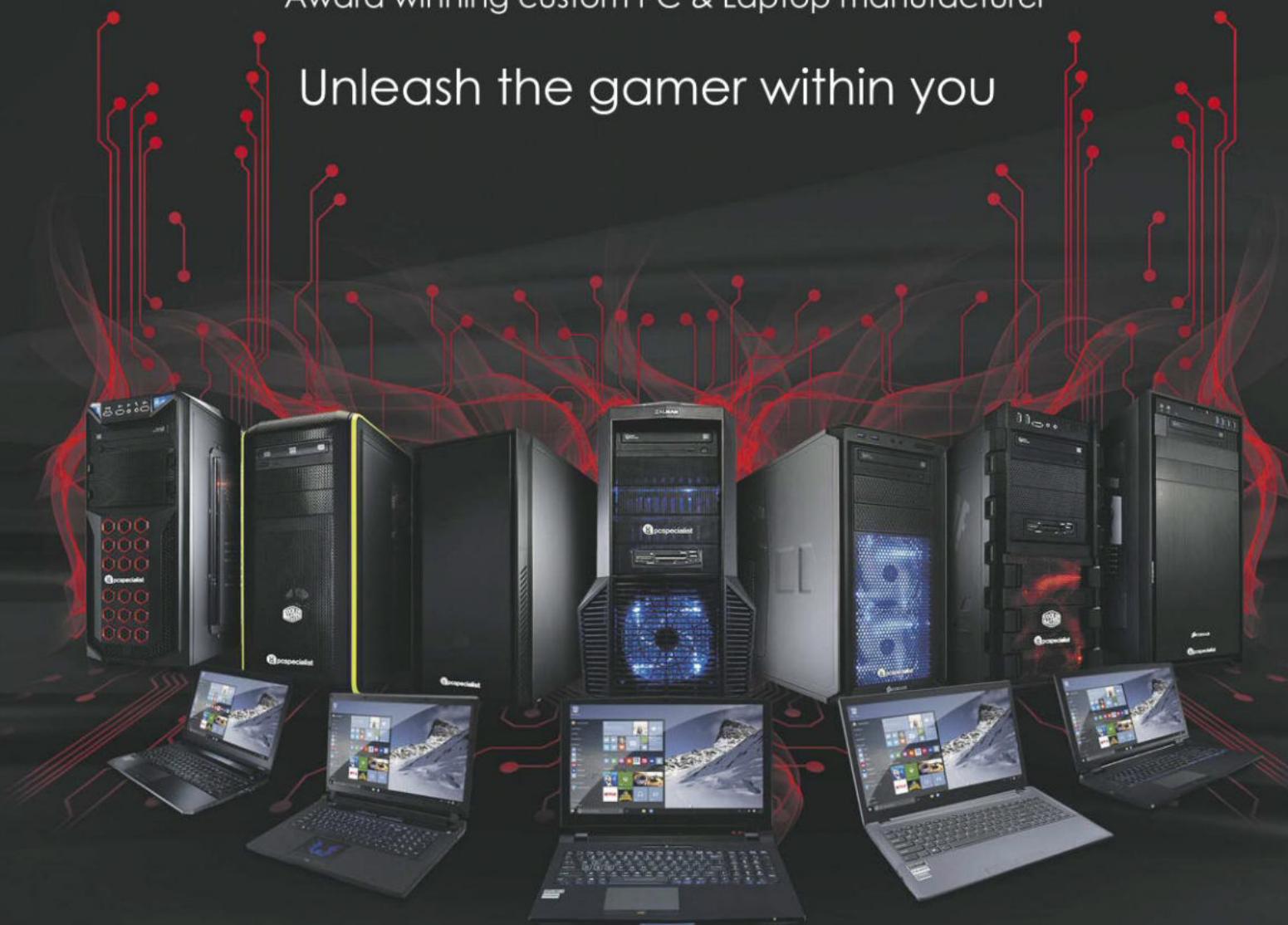
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GOOD V



ON THE LEFT-HAND PAGES:
A growing body of evidence shows it's physically healthy to be a do-gooder. Rita Carter dons her halo and puts forward the case for being kind to fellow humans

Remember that boy at nursery who wouldn't share his toys? How about that flatmate who never did the washing-up? There's no doubt about it, we've all encountered selfish individuals. But don't worry, while it may seem as if these egomaniacs are getting one up on the rest of us, it turns out that the good 'uns will have the last laugh. ▶

ILLUSTRATOR: KYLE SMART



SEVIL



ON THE RIGHT-HAND PAGES:

*Despite the available evidence,
Dean Burnett thinks there is still
a case to be made for looking
after number one – sometimes it's
good to be bad*



All through our childhoods, it's drummed into us that we need to be good: kind, considerate, respectful of others, and so on. Odd, then, that so many people, upon entering adulthood, abandon these principles altogether. They spend their existence being dreadful, cruel and inconsiderate. Why would they do this? One explanation is that being bad works. ♦



● In his 1965 novel *The Tin Men*, British writer Michael Frayn describes an attempt to develop an altruistic robot. The first prototype, Samaritan I, was programmed to sacrifice itself in favour of others. Its designer tested it by putting it on a one-robot raft with various companions to see what happened when the raft started to sink. The robot duly chucked itself overboard with alacrity. However, it did this to save anything from a sack of lima beans to a chunk of seaweed, and the cost of drying it out each time proved expensive.

Samaritan II was adapted to sacrifice itself only for things it judged to be as, or more intelligent than itself. In trials it threw a number of insensate objects overboard, plus one hapless sheep. Yet when it was placed on the raft with another of its kind, both machines chucked themselves overboard simultaneously, which proved even more expensive.

Lastly, the designer inserted a bit of software that stopped the robots from committing reciprocal suicide, but this final version proved to be most expensive of all. When placed together on the raft, the two machines thought about it for a while, then, as the raft slowly sank, they bashed each other to bits.

Our species' history of warfare suggests we are programmed like the later versions of Samaritan. Yet every so often someone behaves like one of those earlier versions: they do something spectacularly altruistic. Stories abound of people diving into the paths of cars to push stray children aside, or throwing themselves onto live grenades to contain explosions that would otherwise kill dozens, or plunging into icy waters to save drowning babies.

Millions of others do quiet acts of giving that rarely feature in newspapers. According to a survey carried out by the Charities Aid Foundation, three-quarters of people in the UK gave money to a good cause in 2014, one-third gave their time and two-thirds helped a stranger. The proportion of people who reported doing altruistic acts had increased on the previous year in nearly every country monitored.

At first, all this niceness doesn't make sense. Selfish people should flourish because altruistic types are metaphorically chucking themselves overboard. ●

Stories abound of people diving into the paths of cars to push stray children aside

Not giving a damn about fellow humans and focusing solely on your own needs can have genuine benefits

● The social brain hypothesis is a theory about how we ended up with such powerful brains. It states that humans evolved in close-knit communities, which required the ability to recognise and process a lot of different relationships with many individuals.

Rather than just looking out for ourselves and our kin, we now had to be aware of the roles, interactions, affiliations and responsibilities of the shared group, and people we had no genetic link to. To do this effectively requires the ability to process a vast amount of information, resulting in an evolutionary advantage for intelligence and abstract thinking. Thousands of years later, here we are. And if you doubt the intense amount of information required to handle different group relationships, then try putting together a table plan at a wedding.

It's debatable whether this social brain hypothesis is the whole story, but it's obvious that our brains are heavily influenced by other people, even down to the neurological level. Contemplating being part of a group has been shown to produce activity in particular regions of the brain, including the cortical midline structures and temporoparietal junctions. Some experts now term this network as 'the social brain', which is different to the social brain hypothesis discussed earlier. Also, brain areas such as the dorsal anterior cingulate cortex show increased activity when subjects contemplate the groups or communities they're part of, suggesting that those we interact with form a strong element of our identity.

Overall, it seems caring about others and being friendly is what made us the humans we are today. That's a nice thought, but it can have some serious downsides, meaning that not giving a damn about your fellow humans and focusing solely on your own needs can have genuine benefits.

For example, the informational influence. If you are around people who all share a common conclusion on an important issue or subject, then you're more likely to agree with it. You'll either say you agree, ☺





Yet according to a slew of scientific studies, the explanation for the apparent proliferation of altruism is that it bestows some kind of benefit on those who practice it. Selfless behaviour appears to be good for your health, mood and even your longevity.

Most obviously, there is the rush of pleasure you get from doing good, the so-called 'helper's high'. Like other types of high, it is thought to come from the production in the brain of morphine-like endorphins.

As well as the feel-good effect of endorphins, they also appear to buffer people against the unhealthy ramifications of stress. In 2013, US researchers interviewed 846 people over the age of 65 about stressful events they had experienced in the past year. They also asked how much help they had given friends or family over the same period, things like doing errands, minding children, giving lifts and so on. When the figures were crunched, it turned out the unhelpful people seemed to have suffered from the stressful events in terms of increased mortality, but those who had been helpful had not. Indeed, helping others seemed to protect people's health in stressful periods more than being helped.

So what is going on in the brains of people who behave altruistically? A study at Baylor College of Medicine in the US showed that helpful people have greater activation in the top and back of their temporal cortex that produces recognition of other people as individuals, a prerequisite for feeling empathy. Similarly, an fMRI study of kidney donors by researchers at Georgetown University found that, compared to non-donors, the donors had more activity in the right amygdala. This is an area of the brain that responds to emotional stimuli when seeing others in distress. The activation pattern is exactly the opposite of that seen in psychopaths.

Empathy, in turn, is associated with the production of oxytocin. This is best known as the 'bonding

Helping others seems to protect people's health in stressful periods more than being helped

By assuming that other humans exist just to inconvenience you, you might end up getting a lot more done

● even if you don't, so you don't stand out (normative social influence), or you'll become genuinely convinced that it's correct, because so many people keep telling you so (informational social influence). Cultivating the ability to not be concerned with – or care about – the views and opinions of others can allow you to make more valid and accurate decisions and conclusions. Others might describe this as 'antisocial', but then you probably can't trust anything they say.

There's also the fact that the most common type of phobia is social phobia; the unreasonable fear of doing something that results in negative judgment or embarrassment from others. This can hamper our ability to do even basic things, like give presentations or complain about poor service. None of this would be an issue if you didn't give a jot about what other people thought of you, so by assuming that other humans are insignificant blobs who exist just to inconvenience you, you might end up getting a lot more done.

There are even those who have learned to exploit the brain's weaknesses when it comes to caring about others. There are several methods, demonstrated repeatedly in experiments, which increase compliance. You can use these techniques to manipulate others into doing what you want. And many people (politicians, car salespeople, cold-callers, etc) frequently use these methods.

There's the 'foot in the door' technique, where agreeing to a small favour makes you more likely to agree to larger ones, if they're of a similar nature. A friend asks to borrow 50p for a bus fare, then £2 to buy a sandwich, and then it snowballs until you're paying their utility bills.

There's the 'door in the face' technique, where you refuse a big request, but doing so makes you more likely to agree to a smaller one. A friend asks to borrow 51





• molecule' and is produced by the bucketload in women giving birth and by loving couples during sex. It even promotes altruistic behaviour. In one experiment, researchers from the University of Bonn asked people to either give money to other volunteers, or withhold it from them, while having their oxytocin levels monitored. Those with the highest oxytocin levels gave away the most, and the act of giving raised their oxytocin levels further. Recipients also experienced a rise in oxytocin, which in turn prompted them to give away more. The escalating hormones mirrored a virtuous spiral of altruism. To add to the good news, other studies have linked high oxytocin levels to better health, including faster healing of wounds.

Putting oxytocin in the water supply is unlikely to cure society's ills, however, because the hormone has a dark side. While high levels increases someone's kindness towards others that they perceive as being 'one of them', it makes them less well-disposed to those they see as outsiders. The same chemical that kindles the best traits in humans may also be the one that kindles the worst.

Still, let's end on an oxytocin-rising note. People buying books in various parts of the UK were recently astonished to find £5 notes tucked between the pages of their purchases. The money was accompanied by a note saying: "Hi, if you are finding this money then know the Universe is smiling at you today. Enjoy a cuppa on me or pass it along to give another a smile to someone else! Have a great day!"

One recipient, Chris Topping from Liverpool, said the note did indeed leave him smiling all day and he decided to do something meaningful with the money.

"We bought some sandwiches and drinks for a few homeless lads and lasses on the way home to pay it forward," he said. "I see a few homeless people in the same spot on a regular basis, so I thought I'd buy enough for all of them." All together now: "aaaahhhhhh!"

Studies have linked high oxytocin levels to better health, including faster healing of wounds

What do you think? Have your say on our Twitter page [@sciencefocus](https://twitter.com/sciencefocus), or email reply@sciencefocus.com

Rita Carter is a science lecturer, broadcaster and writer who specialises in the human brain.



The brain wants us to be liked and to stay in other people's 'good books'. And as a result, we get screwed over

• your car for a week, and you say no. So she asks to borrow it for the weekend, and you say yes. You feel like you're up on the deal, but you're not. You didn't have to let her borrow your car at all. But you have.

There's also the 'low ball' technique, where you'll agree to do something in return for a reward, then the other person removes the reward, but you go through with it anyway. A car salesman says you can have the car with a 10 per cent discount, so you agree. He goes to "speak to his manager". It turns out you can't have the discount, but you buy it anyway. Because your brain is stupid.

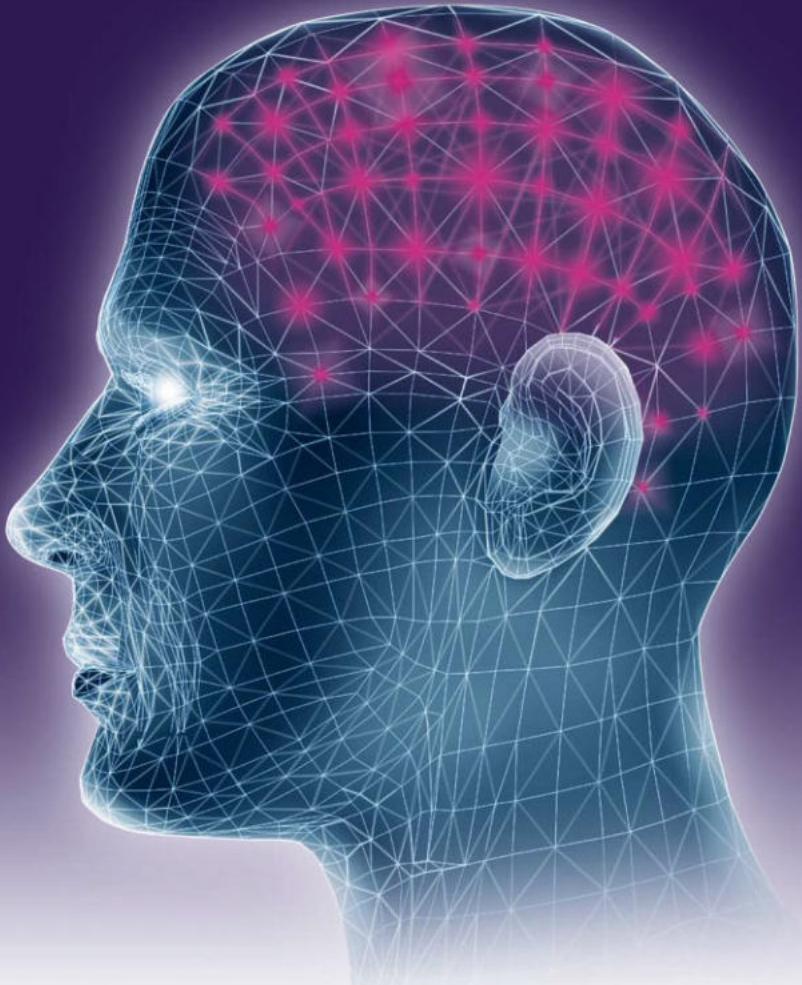
All these stem from the brain wanting us to be liked and to stay in other people's 'good books'. And as a result, we get screwed over. So-called self-centred or antisocial people seem to have shaken off this neurological need for people to like them, and tend to be more successful for it.

It could be argued that the brain isn't even cut out to be altruistic. There's a brain region, the supramarginal gyrus, which suppresses our egocentric bias and stops us from assuming everyone thinks and feels the same as us. But it only works to a certain point; it struggles to let us empathise with people who are in drastically different situations to us. This is why we can watch the plight of overseas famine victims amidst our frivolous daytime TV shows without being reduced to a blubbering mess.

Maybe this empathy and 'compassionate' reflex is just an evolutionary leftover, some sort of emotional appendix we'd be better off without. Because once you do abandon it and start living for yourself and nobody else, you seem to get a lot more done. Just look at any typical politician or CEO. It may not be 'good' to be bad, but it clearly pays well. ■

Dean Burnett is a doctor of neuroscience, psychiatry tutor, comedian and writer. His debut book, *The Idiot Brain*, is available now.

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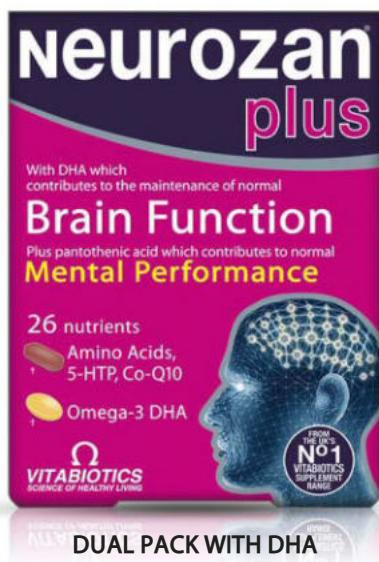


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VITABIOTICS
SCIENCE OF HEALTHY LIVING



HELEN CZERSKI ON... STICKY FINGERS

"BANK TELLERS MOISTEN THEIR FINGERS FOR GRIP, BUT CLIMBERS USE CHALK. WHICH METHOD WORKS?"

H

umans spend a lot of time picking things up and putting them down again. We hardly ever think about it, but whatever we're manipulating – pens, cake, keys, tennis balls or this magazine – it's only possible because our fingers can grip.

Wandering round a stationery shop the other day, I spotted one of those sponge pads that you sometimes see in post offices. Bank tellers use them to moisten their fingers and improve their grip when they're counting banknotes. But then I remembered the years I've spent on climbing walls and on gymnastic equipment. In those environments, it's exactly the opposite. You put chalk on your hands to improve your grip, because the chalk dries your hands out and drier fingers grip better. So which method actually works?

Water is pretty sticky stuff. Water molecules are constantly forming brief alliances with the molecules around them, and those temporary bonds can be pretty strong. But we don't think of water as 'sticky' all by itself, because a water molecule is very small and switches allegiance often. That's why water isn't very viscous – it's easy for those molecules to flow past each other. Water will stick to lots of surfaces, but it won't hold on to other water molecules for long periods of time. Sugar syrup has the same sorts of bonds, but the sugar molecules are far larger, and each one is attached in many places to the ones around it. That's why sugar is thick and viscous – lots of bonds have to be broken for a molecule to move anywhere, and that takes time. But water isn't like that. It's thin and runny, and so it isn't acting like glue.

It turns out that climbers use chalk precisely because water is so runny. Climbing is an intensive activity, so your hands can get quite sweaty. If there's enough water on your fingers to form a complete layer, your fingers don't actually touch the rock directly because of the water in the way. In this case, your fingers have almost no grip. Water sticks to the rock and it sticks to your fingers, but the water layer in between just slides over itself. If you rely on that, you're going to fall off the rock face pretty quickly! So the chalk is there to absorb the water and prevent it ever forming a single thin layer.

The interesting bit is what happens when there's a little bit of water, but not enough to form a complete



layer. This is where the bank teller's damp sponge comes in useful. If you start with completely dry fingertips, you don't have much grip. But as you add tiny amounts of water, your grip improves and keeps improving right up to the point where there's enough for the water to form a proper layer, and then it all gets worse again. What seems to be happening is that a small amount of water softens the top layer of your skin, just a tiny bit. That makes your skin more flexible, and so when you press your fingertip on to a banknote, your skin squishes more into the rough surface. That means that a greater area of your skin is in direct contact with the note. Slightly damp fingertips have much more grip than dry ones.

I am one of those people who always struggles to prise apart the two sides of plastic bags in supermarkets. But now I know the solution: slightly damp fingertips when you try to slide the two sides past each other. It may not look elegant, but science says that it works! ☺

Dr Helen Czerski is a physicist and BBC science presenter. Her book, *The Storm In A Teacup*, will be out in November.

NEXT ISSUE: WHY ISN'T THE OCEAN SEE-THROUGH?

THE HOMININ GAMES

This August, the Olympic Games kicks off in Rio de Janeiro, Brazil. But how would our ancient ancestors have fared against *Homo sapiens*? Let the Hominin Games begin!

Words: Isabelle De Groote Illustration: Miquel Tura Rigamonti



100-METRE SPRINT

Homo neanderthalensis

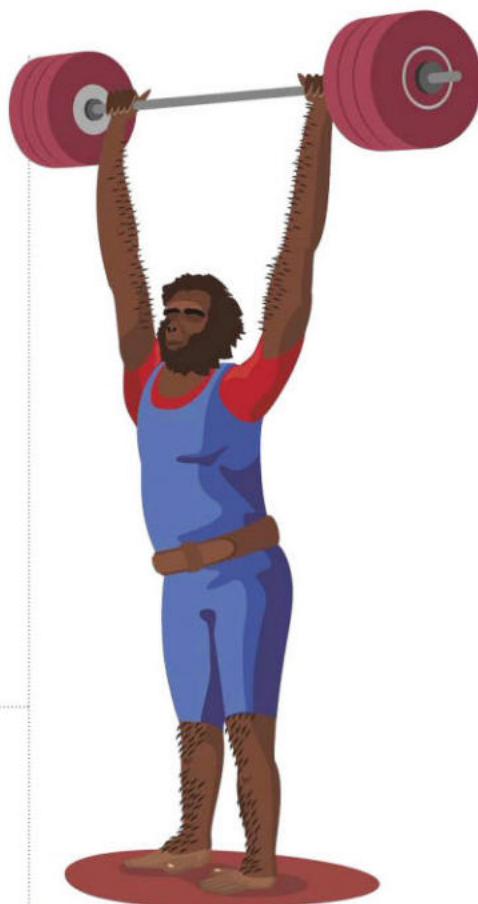
vs *Homo sapiens*

Male world record: 9.58s

(Usain Bolt, Jamaica)

Unlike *Homo erectus*, who hunted in the open woodland and grasslands of Africa, the Neanderthals hunted on Europe's cold steppes. Their stocky, cold-adapted bodies may have made them less efficient at long-distance running, but their superior leg strength, used when hunting animals up close, may have given them a very quick start. Whether they would have had the ability to maintain their speed over an entire 100m sprint, however, is doubtful.

Gold medal: *Homo sapiens*



UNEVEN BARS

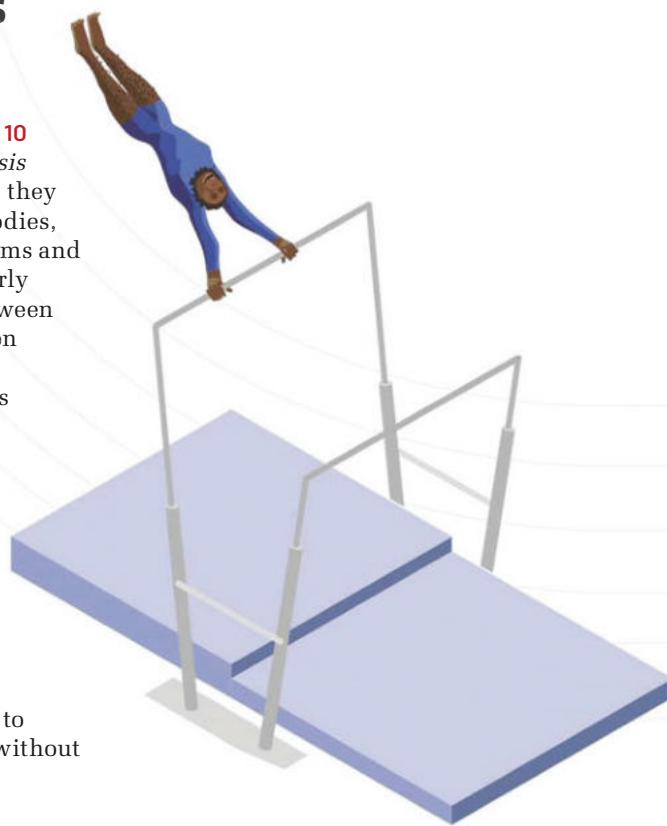
Australopithecus afarensis

vs *Homo sapiens*

World record: Perfect 10

Although *A. afarensis* walked on two legs, they still had ape-like bodies, with long, strong arms and short legs. These early hominins lived between 3.85 and 2.95 million years ago, climbing trees to obtain fruits and shelter from predators. Their low mass and curved fingers, combined with long arms and short stature, would have made them well suited to uneven bars.

They would be able to flip, spin and turn without losing momentum.



Gold medal: *Australopithecus afarensis*

WEIGHTLIFTING

Ardipithecus ramidus

vs *Homo sapiens*

Male world record for clean and jerk: 264kg (Aleksey Lovchev, Russia)

A. ramidus is one of our earliest ancestors, living 4.4 million years ago. It had a body similar to that of a chimpanzee, but probably walked on two legs. They would have had great upper body and leg strength and, like chimpanzees, been two to five times stronger than us. Whereas some of our human muscles are used for fine, controlled motor skills, most of *A. ramidus'* muscles would have evolved for brute strength.

Gold medal: *Ardipithecus ramidus*



FREESTYLE WRESTLING

Paranthropus robustus vs Homo sapiens

Male bantamweight champion:

Dzhamal Otarsultanov (Russia)

These ancient ancestors, who graced our planet 1.8-1.2 million years ago, had large teeth and muscular skulls to consume tough, fibrous foods. Although the males only stood around 1.2m tall and weighed 54kg, they would have been extremely powerful, with long arms and a low centre of gravity. They'd have floored a modern human, tearing him to pieces.

🥇 *Paranthropus robustus*

(although they may have been disqualified)



10,000-METRE RUN

Homo erectus vs Homo sapiens

Male world record: 26:17:53

(Kenenisa Bekele, Ethiopia)

H. erectus was the first ancient human species to leave Africa, spreading to Asia and Europe around 1.5 million years ago. *H. erectus* had a narrow body, long legs, rotating hips and strong neck muscles, making it well adapted to long-distance walking and running. They would have relied on endurance to hunt large game, tracking it to exhaustion, and would have been trained from a young age to cover large distances.

🥇 *Homo erectus*



SHOT-PUT

Homo neanderthalensis vs Homo sapiens

Female world record: 22.63m

(Natalya Lisovskaya, USSR)

The Neanderthals' short, strong arms would have been well trained from preparing hides, making tools and hunting. Neanderthal female arms show well-developed muscle attachments and uneven bone strength between the two arms (due to the right being used more). Neanderthal females had at least 10 per cent more muscle bulk than modern European men, and their shorter arms would have given them greater leverage.

🥇 *Homo neanderthalensis*



JAVELIN

Homo heidelbergensis

vs Homo sapiens

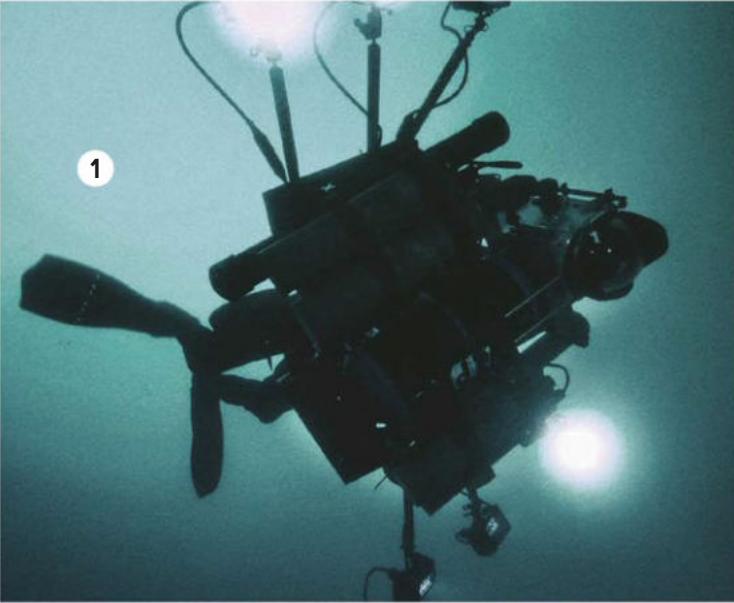
Male world record: 104.8m

(Uwe Hohn, East Germany)

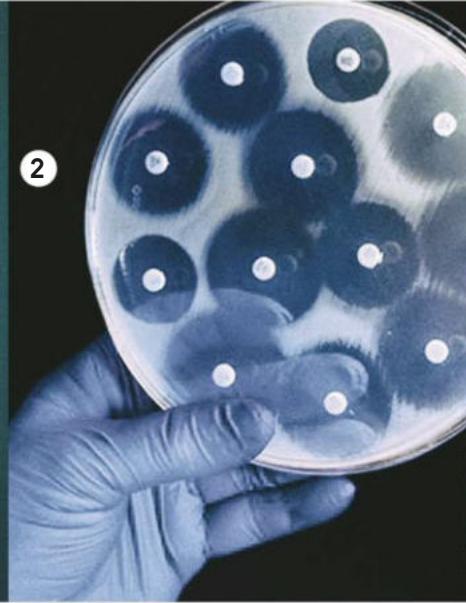
H. heidelbergensis lived around 700,000-200,000 years ago in Europe and Africa. They were the first *Homo* species to truly control fire, and produced the first spears. Some of these may have been stone-tipped, making them more effective at killing large mammals. It's unclear whether *H. heidelbergensis* threw the spears or used them for stabbing, but either way they'd have struggled to beat modern javelin records.

🥇 *Homo sapiens*

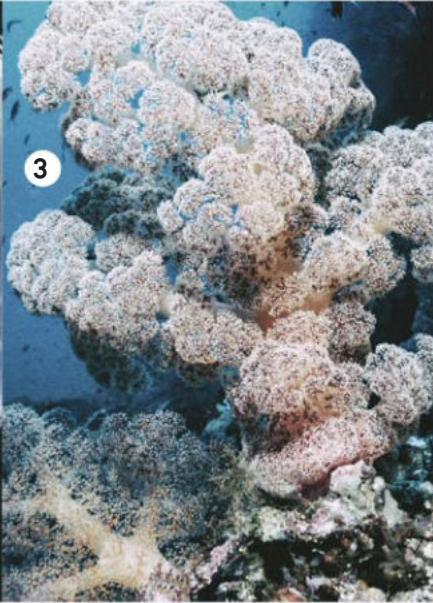
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RAIDING THE OCEAN'S MEDICINE CABINET



PHOTOS: GETTY/X7, FLPA/X7



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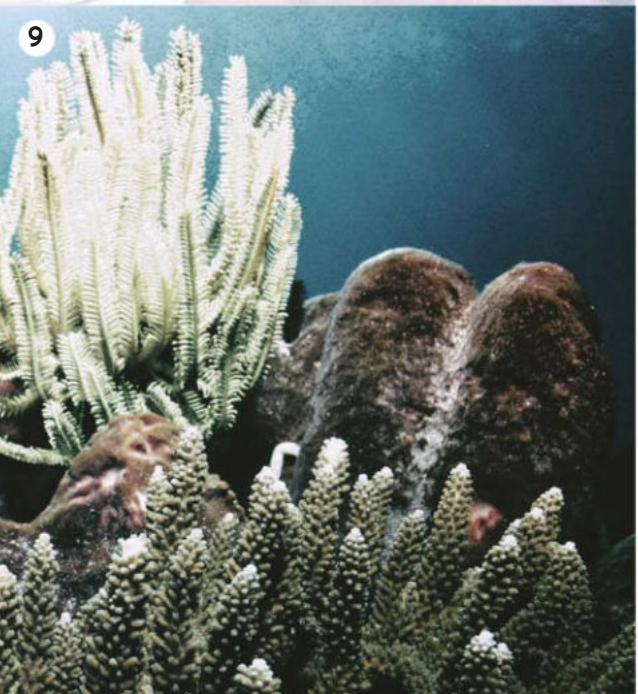
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Antibiotics are losing their effectiveness against disease. But the world's waters could be full of new drugs, just waiting to be discovered

Words: **Helen Scales**



ud and sponges probably don't feature highly on most scuba divers' bucket lists. But scientist and explorer Brian Murphy, based at the University of Illinois at Chicago, has his sights set on the sediments lurking at the bottom of lakes and the gooey animals clinging to submerged shipwrecks. And for good reason. He recently brought back a blob of mud from Lake Michigan and found it contained bacteria that make two previously unknown molecules. Lab tests showed that this class of compounds is lethal to the bacterium that causes tuberculosis, a disease that existing drugs are struggling with. "For millions of years bacteria have fought one another," says Murphy. "We're just harnessing that power."

Around the world, superbugs are on the rise. Earlier this year, two patients in the US were discovered with strains of *E. coli* that's resistant to many antibiotics, including drugs ↗

● that doctors only use as a last resort. It's an alarming trend in which bacteria are gaining the upper hand in their battle against the antibiotics we use to kill them, hastened by the world's overuse of these drugs.

"The way to combat drug resistance is to find new chemistry," says Murphy. He's one of many modern-day prospectors who are searching for that new chemistry underwater.

PLUMBING THE DEPTHS

From icy polar seas to scorching hydrothermal vents, and from coral reefs to inland lakes, the vast, aquatic realms covering seven-tenths of our planet are home to an immense diversity of life. They include many animals that evolved complex chemical defences, along with a profusion of microbes; it is thought that around 90 per cent of oceanic life is microscopic. From among these creatures, researchers are uncovering molecules that could form the basis for new medicines.

Tapping the natural world for pharmaceuticals is nothing new – pop an aspirin and your headache will be soothed by a substance that was discovered in willow tree bark. With the rising tide of drug resistance, the hope is that nature has plenty more in its medicine cabinet for us to dip into. The trick is sifting through all those potent chemicals to find the ones that could fight disease.

"It's no secret that there's an incredibly high failure rate in developing drugs," says Murphy.

The hope is that nature has plenty more in its medicine cabinet for us to dip into

PREVIOUS PAGE:
1 Diving the Great Lakes

2 Testing antibiotics in the lab

3 Animals on coral reefs have evolved interesting chemical defences

4 One of Brian Murphy's students leaps into the water to hunt for new drugs

5 The Great Lakes in the US are a popular dive spot as they contain hundreds of well-preserved shipwrecks

6 Michael Mullaney (left) and Brian Murphy processing deep-sea sediments

7 Gathering Icelandic algae for research

8 Brian Murphy with bacteria he's collected – some of these colonies contain a specific group of bacteria that's widely used in antibiotics

9 Bioprospectors first looked to coral reefs in the 1950s



ABOVE: The Great Barrier Reef spans 344,400km² – that's a lot of area to search for potential drugs

RIGHT: Shipwrecks act as artificial reefs and become colonised with many species



MARVELLOUS MICROBES

Bacteria can help us beat disease, but they can cause problems too

"It's really difficult to find a set of molecules that can target a specific disease and do it within the incredibly complex environment of the human body."

To help with this, Murphy is working to smarten up the sample collection process, as it's one of the few steps in drug development that hasn't seen a major revolution in recent decades. According to Murphy, looking for molecules in original places is an important part of drug development, so he decided to use a new resource altogether: the general public.

Chatting with recreational scuba divers gave Murphy the idea of searching shipwrecks for sponges. These unprepossessing animals spend most of their lives stuck in place, sifting the water for food and taking on hordes of bacteria. "Bacteria can constitute up to 30 or 40 per cent of sponge biomass," Murphy explains.

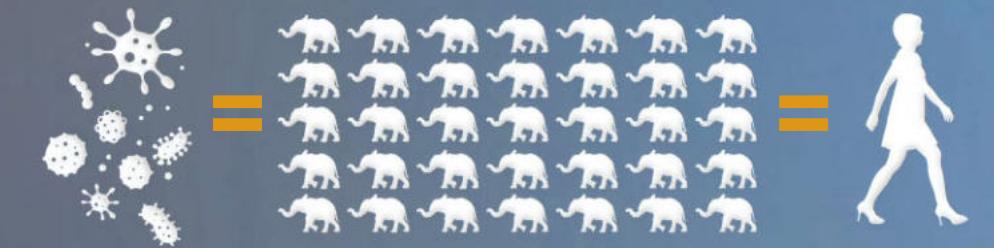
Freshwater sponges are a common sight across the USA's Great Lakes but almost nothing is known about them. Rather than go out himself and gather sponges – a time-consuming and expensive business – Murphy piloted a citizen science project asking divers to collect tiny samples for him while they're out and about. Last summer he sent out collecting kits and got a great response, receiving more than 40 nubbins of sponge in the mail.

This year he's rolling the project out across the Great Lakes and hopes to sample as many sites as possible. Ultimately, Murphy wants to map the distribution of sponges and bacteria across the lakes so that future efforts can be more effective and will zero in on fruitful spots, both in the Great Lakes and beyond.

DIVERSE OCEANS

When bioprospectors first turned to the oceans in the 1950s, their ➤

Microbes living in the ocean collectively weigh the equivalent of 35 African elephants for every person alive today.



In the last 30 years, around half of all new medicines released have been based on molecules found in the natural world.



£69,000,000,000,000

£69tn is the estimated annual cost of global inaction against antibiotic resistance by 2050.



By 2050, 10 million people could die per year (or roughly one every three seconds) if no action is taken to combat antibiotic resistance. That's more than the death toll from cancer and diabetes combined.



63,000 tons

Roughly half of all antibiotics used worldwide are given to food-industry animals to prevent infection and speed up growth rates.



In a survey of 139 academic studies, 72 per cent showed a link between antibiotic use in farm animals and drug resistance in humans.



In 2011, the global market in drugs initially discovered in the sea was worth around \$4.8bn.

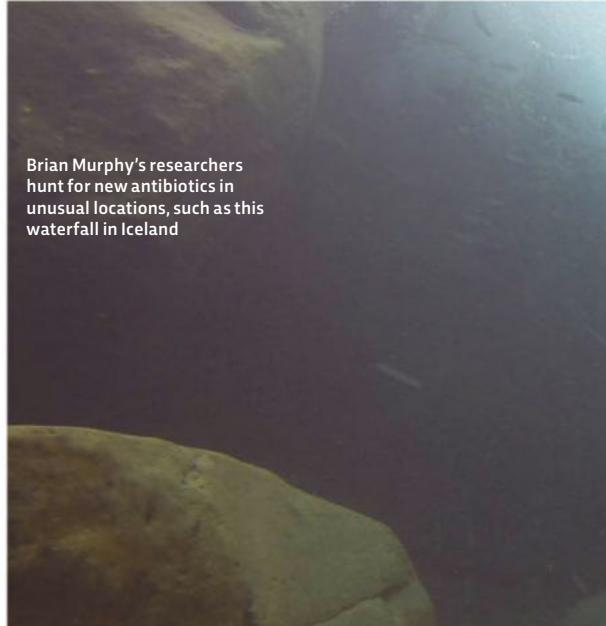
In the US, between 1997 and 2010, 60 per cent of cases of sore throats were treated with antibiotics, even though only 10 per cent were caused by bacterial infection, at a cost of \$500m.



Vancomycin was introduced in 1972 against drug-resistant strains of 'superbugs'. After seven years, bacteria began evolving resistance to the drug.



Brian Murphy's researchers hunt for new antibiotics in unusual locations, such as this waterfall in Iceland



ABOVE: PharmaSea researchers scouring through oceanic mud

BETWEEN: Some sea squirts contain cancer-fighting agents



Initial targets were coral reefs. These bustling ecosystems, packed with species, are a logical place to look and they've yielded many natural products, including some that made it to the end of the drug development pipeline. Early on was chemotherapy agent cytarabine, approved in the US in 1969 and originally found in a sponge on a Florida Keys reef. Another cancer-fighting agent called trabectedin, from a Caribbean sea squirt, has been used in Europe since 2007 and in the US since 2015.

Elsewhere, other researchers are hunting for novel chemistry even further beneath the waves. An international team called PharmaSea, led by Prof Marcel Jaspars, is searching for new antibiotics in the deep sea, including at the bottom of trenches – the deepest parts of the oceans. Jaspars describes these as 'negative islands' sticking down into the seabed, instead of pointing up. "It's possible there have been millions of years of separate evolution in each trench," he says. Jaspars and his collaborators send unmanned

probes miles down into the depths to bring back mud loaded with unique bacteria. Techniques for keeping these extreme creatures alive in the lab have advanced in recent years, so experiments can be carried out. According to Jaspars, they've done around 100,000 tests, with targets including the so-called ESKAPE pathogens. This group of six bacterial strains are showing growing resistance to multiple existing antibiotics.

Ultimately, the PharmaSea team aims to narrow down two compounds that can be produced at a larger scale and put forward for pre-clinical trials. So far, their most promising finds are compounds that could be effective against diseases of the nervous system, in particular epilepsy and Alzheimer's disease.

BENEFITS FOR ALL?

But who owns these discoveries from the deep? The word 'bioprospecting' usually has a negative connotation. At worst, it brings to mind indigenous people giving away their knowledge of traditional medicines and

UNDERWATER PHARMACY

These creatures contain chemicals that could beat cancer, MRSA, and more



HORSESHOE CRABS
The blood of these arthropods is packed with amoebocyte cells that react to tiny traces of bacteria. Their blood has been used for the last 50 years to test equipment and vaccines for contamination.



CONE SNAILS
The stings of these molluscs contain conotoxins. There is already a conotoxin-based painkiller that's more potent than morphine. There are also cancer and diabetes treatments on the horizon.



SPINY STARFISH
This starfish's body is covered in slime consisting of 14 per cent carbohydrate and 86 per cent protein. The substance is being investigated as a treatment for arthritis and asthma.



PUFFERFISH
These fish contain tetrodotoxin (or TTX). This is what makes fugu (a delicacy made from pufferfish) a risky dinner. TTX is being developed as a treatment for the pain suffered during chemotherapy.



MICROCOCCUS LUTEUS
This bacterium produces a pigment called sarcinaxanthin that can block long-wavelength UV radiation. This could be used in the development of more effective sunscreens.



DENDRILLA MEMBRANOSA
This sea sponge contains a molecule called darwinolide. This substance has been found to be effective against the drug-resistant MRSA 'superbug', which can often cause problems in hospitals.



ELYSIA RUFESCENS
This species of sea slug has a wide distribution. It contains a substance called kahalalide F, which is currently under investigation as a potential tumour-fighting agent.

receiving little reimbursement. Thankfully, things have moved on, and protocols for sharing benefits are now commonplace. Prior to collecting anything, researchers will generally enter written agreements with the country of origin. In 2010, the international Nagoya Protocol came into effect, making such agreements a legal requirement. But not everyone is signed up to Nagoya – the US is notably absent.

The high seas begin 200 nautical miles from shore and don't technically belong to anyone, making them difficult to police. Currently, the UN Convention on the Law of the Sea (UNCLOS) covers certain activities including deep-sea mining and laying cables, but it says nothing about biodiversity. Formal discussions got underway in March this year to amend UNCLOS to encompass bioprospecting. Various views are on the negotiating table. "The G77 and China believe that it should be the Common Heritage of Mankind, which would mean everybody could benefit," explains Jaspars. The idea is that one single nation or

"It's possible there have been millions of years of separate evolution in each trench"

company shouldn't be allowed to solely benefit.

On the other hand is the concept of Freedom of the High Seas, backed by the US and Norway, which would give any nations freedom to bioprospect in the high seas, just as anyone can fish there. They could research anywhere and hold on to the profits. Other groups, including the EU, are keen to find a solution. It's likely to be several years until bioprospecting in the high seas becomes regulated.

NEW WAYS AHEAD

Back in the lab, Murphy's tuberculosis-busting molecules are entering the next round of tests to see if they could lead to new medicines. Even if they don't, Murphy is confident they will still

be useful. "They showed very selective antibacterial activity towards tuberculosis," he says. Other bacteria were left untouched. Finding out exactly how these molecules selectively kill the tuberculosis bacterium could reveal vital information about the disease itself and perhaps point the way towards effective medicines.

But bioprospectors will have to hurry. This summer has seen the ailing Great Barrier Reef make headline news around the world, and human activities continue to threaten the health and biodiversity of Earth's oceans, rivers and lakes. Let's hope we can find the drugs and cures we need before our planet's waters become irrevocably sickened.

Helen Scales is a marine biologist and writer. Her most recent book is *Spirals In Time*. She tweets from @helenscales.

DISCOVER MORE

Listen to *The Life Sub Aquatic* with Helen Scales about the human obsession with living beneath the waves at bbc.in/1pLnvLI

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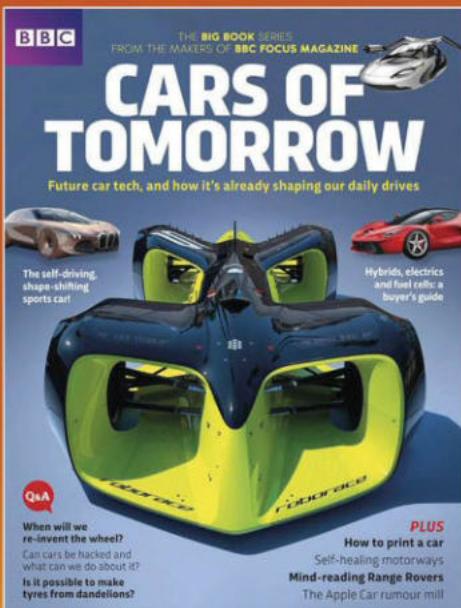
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ROBERT MATTHEWS ON... ANIMAL EXPERIMENTS

"ANIMAL EXPERIMENTS SOMETIMES PREDICT WHAT'LL HAPPEN WITH HUMANS, BUT OFTEN FAIL TO DO SO"

R

eincarnation is highly unlikely. But in the event that it is possible, I know what I'm coming back as:

a mouse. Hardly a week goes by without scientists announcing they've cured some of these furry cheese-eaters of yet another disease, from cancer and AIDS to Alzheimer's.

So how come we humans are still succumbing to these diseases? Aren't animal experiments supposed to be reliable signposts towards the next miracle cure?

They certainly have the backing of the Royal Society, Britain's premier scientific academy, which insists that "virtually every medical achievement in the past century has depended directly or indirectly on research using animals". And the Royal Society doesn't make statements like that without evidence to back them up.

Actually, its website doesn't give the evidence, but there's an obvious explanation: there have been so many medical achievements over the last 100 years it would take up too much space to list all of those based on insights from animals. Yet there's not even a reference to a research paper, or indeed any source cited at all. The claim is simply stated, as if only a hamster-cuddling moron could possibly doubt it.

Driven perhaps by my fondness for cuddling hamsters, some years ago I decided to see if I could find the evidence to support the claim. After all, if there were, it would at least suggest the current spate of disappointment is just a temporary blip.

Yet after spending days rummaging through the academic literature, I drew a blank. Actually, that's not quite true. I found the same statement had been made by other scientific bodies, but again with no detailed evidence to back it up.

I eventually tracked down its origins to an article in a newsletter published in 1994, attributed to the US Public Health Service. It has no author, no references



and nothing but a few anecdotes to stand it up.

Frustrated, I began my own search for evidence of the reliability of animal experiments in medical research, and made a shocking discovery. Only a handful of studies had even addressed the issue. Those that did were often botched or meaningless, but the studies that made some kind of sense suggested that animal experiments are about as reliable as tossing a coin.

I published my findings in a medical journal, hoping to spur better research into the issue, and was promptly attacked by pro-vivisection campaigners. One dismissed my work as "pointless and pedantic point-scoring".

Fortunately, the research community took a more constructive approach, and set up studies to find out how reliable animal experiments are. Now the results are starting to emerge, and they're not exactly reassuring. They suggest that while animal experiments do sometimes predict what will happen with humans, they also often fail to do so, and there's no simple way of telling which case applies.

For example, an international team has just published a major study of whether tests on mice can predict drugs' common side effects, like fatigue and headache. The results suggest the tests are useless at best, and sometimes positively misleading.

The study's authors, which include scientists from leading pharmaceutical companies, say that "care should be taken" in the interpretation of animal experiments.

Certainly, care should also be taken over claims of 'breakthroughs' based on such experiments, or statements made by top academic institutions on the basis of no evidence at all.

Robert Matthews is visiting professor in science at Aston University, Birmingham. His latest book *Chancing It: The Laws Of Chance And What They Mean For You* is out now (£14.99, Profile).
NEXT ISSUE: THE VOLKSWAGEN EMISSIONS SCANDAL



PHOTO:ISTOCK

Could a pig's heart save your life?

THOUSANDS OF PEOPLE ARE IN DIRE NEED OF A TRANSPLANT IN THE UK, BUT THERE JUST AREN'T ENOUGH DONATED ORGANS TO GO ROUND. SO SHOULD WE MAKE UP THE DEFICIT WITH ANIMAL ORGANS?

WORDS: MICHAEL REISS

Michael is professor of science education at University College London and a priest in the Church of England. He has advised the House of Lords on the use of animals in scientific procedures and was the ethicist on the Farm Animal Welfare Committee (FAWC) from 2004 to 2012.

I

arlier this year it was announced that researchers at the National Institutes of Health (NIH) in the US had kept a genetically engineered pig's heart beating in a baboon for three years. Though it was undoubtedly a headline-grabbing story, there are serious implications for the research. Every year, several million people die worldwide because of transplant shortages. There just aren't enough human organs from tragedies like road accidents to go around. But some scientists are working on a radical solution – to use organs from animals.

Xenotransplantation, as the procedure is known, may sound like something from a science fiction movie but doctors and scientists have been trying to develop it for decades. Back in 1984, Stephanie Fae Beauclair, generally known as 'Baby Fae', was born with a heart defect that would have killed her within a week or so. At that time, transplants using infant human hearts were nearly always unsuccessful. But her surgeon, Leonard Lee Bailey, was a pioneer in animal-animal transplants so decided to try transplanting a baboon heart. The hope was that it would allow Baby Fae to live long enough for a second operation to replace the baboon heart with a human one.

The surgery was initially a success, but Baby Fae died 21 days later when the heart was rejected by her body. Nevertheless, her sad story marks the first serious attempts at xenotransplantation. But 30 years on there are still many questions to be answered. Is xenotransplantation even feasible, and is it ethical?

INGENIOUS IMMUNITY

Our immune system is a wonderfully complicated collection of cells and organs that helps to protect us against any foreign bodies that invade and cause disease. Intruders,

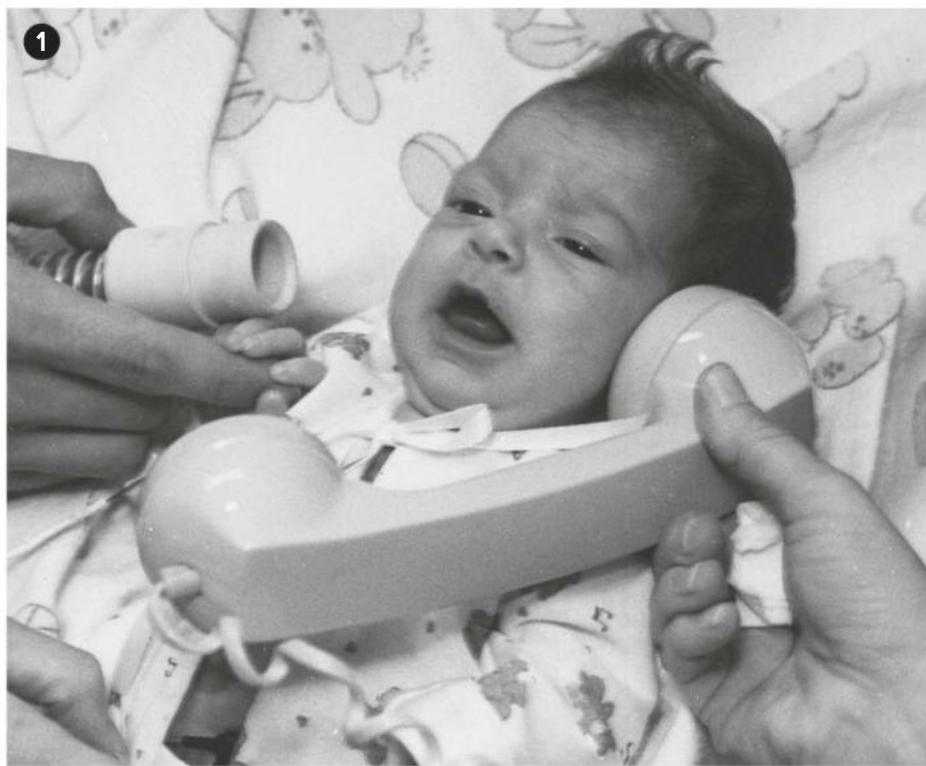
such as viruses or harmful bacteria, are attacked by highly specialised cells. Each of us has the physiological ability to recognise that our body and its organs are 'ours' and that invading objects are not. So while the white blood cells and other components of our immune system attack foreign biological objects inside us, they do not attack us. The advantage of this is obvious: disease-causing organisms can be attacked and destroyed without the body turning against itself.

However, there is a serious downside when it comes to transplantation. The immune system can recognise the transplanted organ as foreign and attack it. To prevent this, patients receiving human-to-human transplants generally have to be given large doses of immunosuppressants to damp down the immune system and prevent it from attacking the transplanted organ. Unfortunately, patients with suppressed immune systems are less able to fight off germs, so they are more likely to catch infections. With a weakened immune system, even common diseases can prove very serious. However, this is less of a problem with the latest immunosuppressant drugs available.

When it comes to transplanting non-human organs such as a pigs' hearts into humans, an extra difficulty arises. Within hours of the transplant, even if immunosuppressant drugs are used, so called 'hyperacute rejection' typically sets in and the transplant fails. In an attempt to overcome this problem, researchers are genetically engineering pigs to carry a single human gene that allows them to produce a human protein on the surface of their internal organs. It is hoped that this will trick the immune system into thinking the organ is human, therefore avoiding hyperacute rejection.

But rejection isn't the only problem that we face if we receive a transplant from another species. Pigs are the species of choice for human xenotransplantation. They are about the same size as we are, they are easy to keep in captivity and their physiology is surprisingly similar to ours, despite being less closely related to us than apes and monkeys. However, a lot of nasty human diseases result from viruses that come from animals. Pigs can carry as many as 50 porcine endogenous retroviruses, endearingly abbreviated to 'PERVs'. ☀

Pigs are easy to keep in captivity and their physiology is similar to ours, despite not being closely related to us

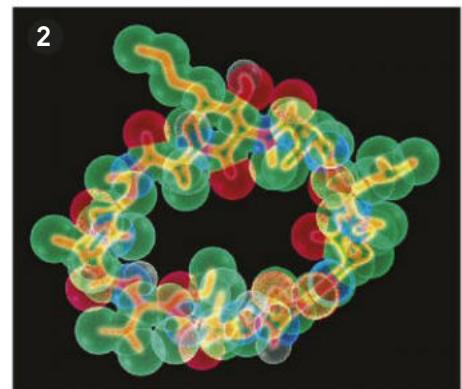


1

1 'Baby Fae' received a baboon's heart in 1984, but died 21 days after surgery when her body rejected the organ

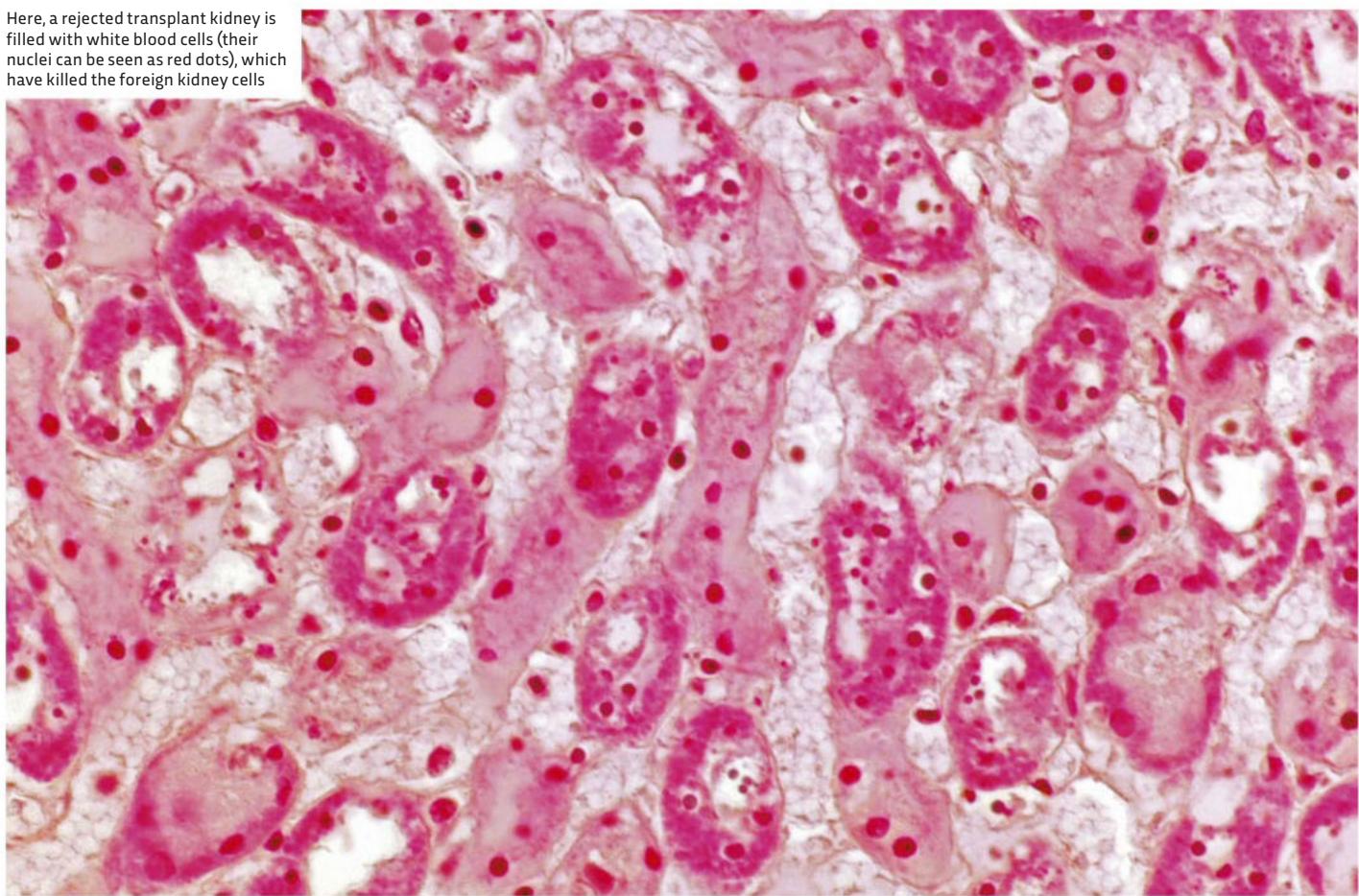
2 Immunosuppressants such as cyclosporin are taken by recipients of donated organs to reduce the risk of rejection, but they make the immune system less effective

3 Frederick West after receiving the UK's first heart transplant in May 1968; he died 46 days later from an infection, caused by weakened immunity



3

Here, a rejected transplant kidney is filled with white blood cells (their nuclei can be seen as red dots), which have killed the foreign kidney cells



A macaque recovers after receiving a liver transplanted from a pig



● These are largely not harmful to the pig but can infect other species. This is what happened in 2009 when a pandemic caused by swine flu led to about 250,000 human deaths.

DO WE NEED XENOTRANSPLANTATION?

Each year tens of thousands of lives are saved as a result of human-to-human transplants. Indeed, the large majority of people waiting for a transplant never receive one. So what can we do about this?

The purchase of human organs – a market-led ‘solution’ to the shortage – is generally illegal. Iran, however, is one of the few countries that permits the sale and purchase of kidneys. As a result, the waiting times for kidney transplants in Iran are much shorter than elsewhere in the world. The going rate is about \$4,000, if you are interested...

However, the primary reason why most people waiting for a transplant never receive one is that there simply aren’t enough human organs to go around. There are several explanations for this. For one, the number of people who would benefit from a transplant continues to rise. This is partly because advances in transplant surgery mean that it is now possible to transplant more organs, and partly because an increasing range of medical conditions can now be treated by transplantation.

Another point to take into consideration is the fact that only a tiny proportion of deaths result in organs that are suitable for use in transplants. Deaths from motor vehicle accidents provide a high proportion of suitable organs. But thanks to improvements in road safety, the use of seat belts, improved car design, better roads, more speed limits, tougher driving tests and greater use of motorcycle helmets, the number of people killed in road accidents is falling.

A final issue is that many countries have some sort of ‘opt in’ rather than ‘opt out’ system for organ donation. This means that for a transplant organ to become available, the dead person needs to previously have expressed a wish for their organs to be used for transplantation – by carrying a donor card, for example – and doctors must also obtain the consent of the donor’s relatives.

WHAT ABOUT WELFARE?

The extent to which animals can suffer is still argued, yet there is increasing acceptance that our closest evolutionary relatives have the necessary brainpower to experience suffering of some kind. A growing number of biologists

and philosophers agree that, at the very least, the majority of mammals can suffer.

So would xenotransplantation lead to significant amounts of animal suffering? Consider, first of all, the pigs that are likely to be used. Companies involved in research on xenotransplantation maintain that their pigs are looked after extremely well. Indeed, in my experience, the animals used in the research are looked after better than pigs on most pig farms, in terms of the conditions in which they live. But there is more to the welfare of the pigs than their housing. For a start, the pigs used in the research are subjected to a number of surgical procedures. When clinical trials begin in earnest, it seems likely that ‘gnotobiotic’, or germ-free, animals will be needed. Such animals would probably be obtained by what is sometimes called ‘surgical derivation’. This means that shortly before birth, the entire uterus with the piglets still inside would be removed from the mother. The piglets would then be raised in isolation and in sterile conditions. From the pigs’ point of view, this doesn’t sound like much of a life, as pigs are social creatures.

Furthermore, it is not only pig welfare that needs to be considered. Current research aimed at improving the success of xenotransplantation has meant that thousands of primates, including captive-bred macaques and wild-caught baboons, have already been used in surgical operations as recipients of the transplants. When viewing many of these operations from the perspective of the scientists, surgeons, and ultimately the patients and shareholders who may benefit, many of these operations are deemed a research ‘success’. From the point of view of the non-human primates, however, there’s little doubt that these operations lead to considerable pain and a dramatic shortening of lifespan.

NATURAL VS UNNATURAL

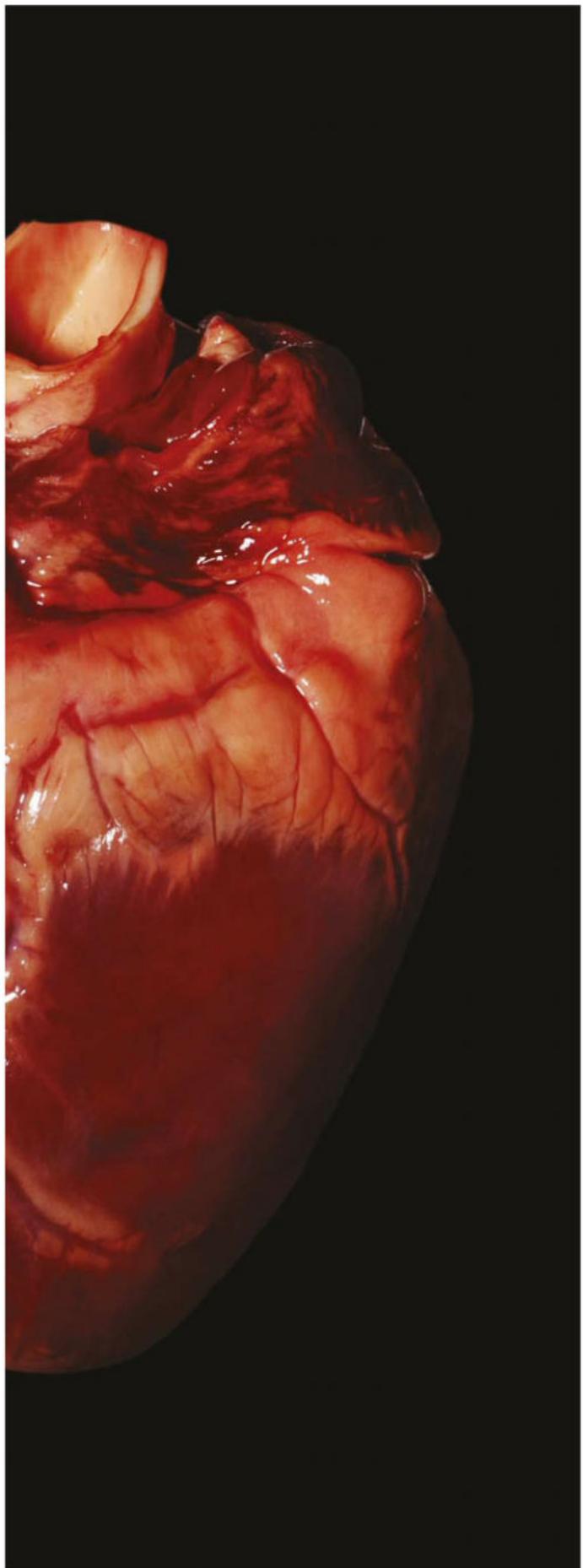
Let us assume that xenotransplantation will require the genetic engineering of pigs through the insertion of one or more human genes into pig DNA. This involves changing the ‘nature’ of the pigs in at least some sense. Is this morally acceptable?

A frequent cry against genetic engineering of any sort is that it’s ‘unnatural’. However, this objection is difficult to defend. After all, what is ‘natural’? Smallpox, tidal waves and death are natural, whereas vaccines, mobile phones and foreign holidays are not. In other words, in everyday language, there doesn’t seem to be much of a relationship between what is ‘natural’ and what is good.

Even so, the ‘unnatural’ argument still has its defenders. A number of religions argue that, at least to some extent and in some sense, nature is good. In the Jewish and Christian traditions, the understanding is that on the sixth day “God saw everything that he had made, and behold, it was very good”. Death and decay entered the world through sin, but even after the fall of man, enough of God’s goodness is present in the ☽

Iran is one of the few countries that permits the sale and purchase of kidneys. The going rate is about \$4,000

The human heart (left) and pig heart (right)
share a strikingly similar anatomy





Pigs raised for xenotransplantation would probably need to be kept in a sterile environment, so would not be able to forage and play with other pigs

creation for much that is natural to be good. An entire theology of natural law has built up around this notion.

Nature is also seen as an indicator of goodness by many others, including those who do not follow any religion. To this day, there is a considerable body of opinion holding that 'natural' practices are preferable to their 'artificial' alternatives. Common examples include the 'breast is best' campaign for child nutrition, organic farming and the call to eat fresh rather than processed food.

Yet one great advantage of nature is that it has been around for quite a while. Consciously or otherwise, many of us think that our ancestors successfully brought up children, farmed and prepared food in 'natural' ways, so these traditional approaches must be okay. After all, and quite logically, one cannot be sure about the long-term consequences of any new technology, genetic engineering included, only of practices that have been around for a considerable time and are now considered 'natural'.

But does the type of genetic engineering really change the nature of pigs? From the pigs' point of view, it can be argued hardly at all. The

practicalities of genetic engineering have significant welfare implications but it seems difficult to argue from a pig's perspective that the genetic engineering itself has changed its nature. The pig's behaviour is no different; its mental capacities and experiences are unchanged. The only difference is that it produces an extra internal protein. Traditional breeding, on the other hand, has resulted in incredibly significant changes to the natures of farm animals, including, for example, increased tolerance of high stocking densities, increased domesticity, and massive changes in milk, wool and meat production.

HOW WOULD YOU FEEL?

How would you feel about the thought of a pig's heart inside you? It is difficult to predict and would likely vary from person to person. Some people might condemn the idea on the ground that it is unpleasant or unnatural, but then the alternative may be death, which most of us don't like much either. It's worth noting that when human-to-human heart transplants were first introduced, some commentators said that they were deeply immoral. Yet we rapidly got used to the idea of human-to-human transplants, and most people on the receiving end are deeply grateful for them. Could we see the same thing with xenotransplantation? Only time will tell.

DISCOVER MORE

Would you accept a pig's heart? Have your say on our Twitter page, @sciencefocus, or email reply@sciencefocus.com

To find out more about organ donation, call 0300 123 2323 or visit organdonation.nhs.uk

Some might condemn pig transplants on the ground that it is unpleasant or unnatural, but then the alternative may be death

10 GADGETS TO UPGRADE THE BRITISH SUMMER BARBECUE

Words: Daniel Bennett



1 SUNNY SIDE UP

Smoke-induced blindness, questionable chicken and overcooked sausages are the hallmarks of a British barbecue. Thankfully, the Big Green Egg (pictured left) is here to save us from all three.

The design itself is nothing new. It's based on a traditional Japanese kamado oven. Where the Egg gets interesting is in its use of materials. It's built out of a space-age ceramic, first developed by NASA to protect its Space Shuttle from the extreme temperatures generated punching through Earth's atmosphere. This means two things: coals last longer since the ceramic readily retains the heat

and, I'm told, you can cook when the mercury drops to -34°C, so even Inuits can have a barbie.

Ultimately, the real benefit is control. With two small vents – one at the base and one at the top – and a thermometer, the heat is easy to adjust, whether you're after a low and slow 100°C for smoking or a furious 700°C for crisping up a pizza. Tinkering with the vents and getting the right amount of coal, takes time at first, but once you've reached your target temperature it stays there – which is why the Egg is favoured by so many top chefs.

Inside, you can cook on a 'plate-setter' platform or directly on the grill. The former safeguards your food from the direct

heat from the coals, allowing hot air to infuse the meat and veg with smoke while cooking it evenly. If you do want a bit of charring, meat can be finished on the grill. The results are hard to fault, which is a relief given the huge outlay. But considering the sturdy build, we'd venture to say that the Egg could last a lifetime.

Don't be fooled by the Minimax moniker, this Egg is back-strainingly heavy and voluminous enough to fit a whole chicken. Meanwhile, the largest model comes in at 213kg, and can fit a whole suckling pig for when you presumably have a medieval banquet to prepare for.

Big Green Egg Minimax
£550, biggreenegg.co.uk

2 FLAME ON

Although the Looflighter sounds like a product you might use in the loo, this piece of kit will kindle your inner pyromaniac. It blasts out a jet of air at 650°C, so when you place it by a pile of coal, it'll glow and crackle in under 60 seconds. We were sceptical, but it's the only way we know of to heat a barbecue to cooking temperature in under five minutes.

Looflighter
£65.95, looflighter.com



3 SOUND OFF

The ghetto blaster is back, bigger and badder than ever before, and now with Bluetooth and a 14-hour battery life. Braven's tough casing means the XXL can withstand falls, sand and even the rain that will almost inevitably ruin your barbecue. Compared to other outdoor Bluetooth speakers at this price, it offers some of the best audio quality we've heard, with a thumping bass. Not a surprise given how much of a workout it was to lug around.

Braven BRV-XXL
\$349.99 (£270 approx),
braven.com



4 CLEANS UP GOOD

Admittedly not many barbecues end up with you needing to drink water from a pond, but this water bottle is so smart we couldn't resist. The LifeStraw Go has a two-stage filtration process for your water. The first is a porous fibre

membrane with holes so small that bugs and bacteria can't get through, which is 99.9999 per cent effective. Then, a carbon capsule absorbs any compounds that might make the water taste or smell a bit funky.

LifeStraw Go
£42.95 (£36 approx),
lifestraw.com



5

PRACTICALLY PERFECT

This humble charcoal burner (pictured below) has been dotted along the kerbs of India's bustling cities for years, powering their love of street food. Now it's selling out in the UK. It might look low-tech on the pages of *BBC Focus*, but its pared-down design is a masterclass in efficiency. We used the 'rocket stove' version that burns charcoal, but it also comes as a woodburner. Simply pop a handful of coals in the top and a firelighter on the shelf below, and within 15 minutes you'll have a workable stove/barbecue, regardless of how much bluster the British summer throws at you. The top supports a grill, a pan or a kettle if you're camping, and it's so efficient that a shopping bag of coal will last a week.

Prakti rocket stove
£64.99, thecharcoalburnercompany.co.uk



6

NO SCRUBS

There are few tasks in life that aren't made more fun by involving a robot. This small, noisy bot has three wire brushes that spin furiously as it runs laps around your grill, using the lid as a guide. Before shutting the Grillbot in – it will just fall off if you don't – you tap a button to set it to clean for 10, 20 or 30 minutes. The clean was usable but not sparkling – the emphasis here on novelty over utility.

Grillbot Robotic Cleaner
\$129.95 (£99 approx),
grillbots.com

7

ICE COLD

A veteran of American summer barbecues – where it's certified as bear resistant – the Peli Cooler is coming to the UK. With a raised floor to allow airflow beneath and 5cm-thick polyurethane insulation, the cooler will keep ice frozen for 10 days. And after a two-week-long meat fest, there's a valve in the base for pouring out water.

Peli 20Q Cooler Case
£184.33,
peliproducts.co.uk



8

LIGHT IT UP

Most British barbecues end up in the dark, so these solar-powered lights are perfect for sprucing up the backyard without too many wires. While most solar-powered lights struggle to compete with anything plugged in to the mains, these LEDs stand out. Plus, there's the option to charge via USB for when the weather doesn't play ball.

Lumify 100 LEDs
£29.99,
thesolarcentre.co.uk



9

LOOK ON THE BRIGHT SIDE

If all this fire and ash is a bit Stone Age for your liking, then here's a more fitting device for the future. The SolSource harnesses the Sun's rays with a reflective dish that focuses beams onto the underside of a grill. It'll provide 300°C of heat, which is adjusted by moving the mirrors. One for the eternal optimist.

SolSource Solar Stove
\$499 (£384 approx),
oneearthdesigns.com



10

PIZZA CAKE

For the hungry individual, the sight and smell of a wood-fired pizza oven on a dusky summer evening is a magical thing – but who's got the time to build one from scratch? Uuni's lightweight, portable oven took just 20 minutes to put together,

even with our notorious sausage fingers.

Uuni's own wood pellets feed into the back and a blowtorch or some lighter fluid will get the temperature in the oven climbing to 500°C within 10 minutes. The fuel is topped up via a hopper at the back, so it's easy to keep the oven running all evening.

The blistering heat takes just two minutes to transform a pale and doughy base into a crispy, golden pizza, though you'll need to turn it after 60 seconds for an even cook. The Uuni comes with a 'peel' for sliding the pizza in and out without singeing your fingers. Clean up and packing is a breeze too, since the pellets burn cleanly and the legs fold neatly away.

Uuni 2S wood-fire oven
£199, uk.uuni.net



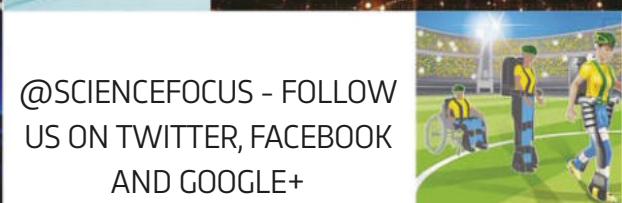
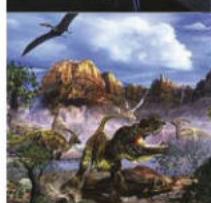
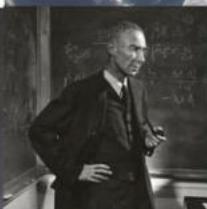
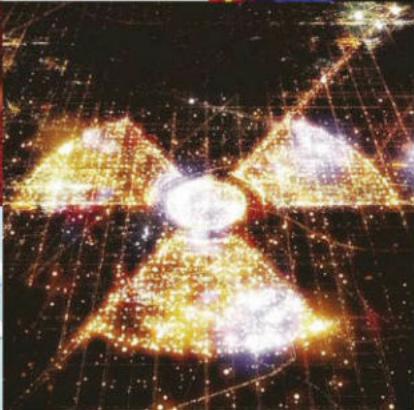
Daniel Bennett is the acting editor of *BBC Focus* magazine.



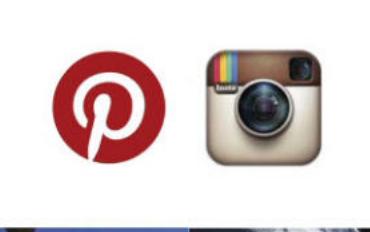
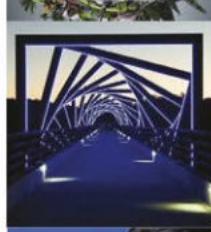
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Q & A



DR
CHRISTIAN
JARRETT

Christian is a psychology and neuroscience writer. His latest book is *Great Myths Of The Brain*.



DR
ALASTAIR
GUNN

Alastair is an astronomer at the Jodrell Bank Centre for Astrophysics at the University of Manchester.



PROF
ROBERT
MATTHEWS

Robert is a physicist and science writer. He's visiting professor in science at Aston University.



DR PETER
J BENTLEY

Peter is a computer scientist and author who is based at University College London. His latest book is *Digitized*.



LUIS
VILLAZON

Luis is a freelance science and tech writer with a BSc in computing and an MSc in zoology from Oxford University.

YOUR QUESTIONS ANSWERED

AUGUST 2016

EDITED BY EMMA BAYLEY

Could global ice melt affect the Earth's tilt?

MAX JONES, USA

The Earth's axis isn't perfectly upright relative to its orbit, but instead is tilted at an angle of around 23.5°. This so-called obliquity has long been known to change slightly over thousands of years as a result of the gravitational influence of the Sun, the Moon and the other planets. But evidence is also emerging for effects resulting from climate change. In 2013, researchers at the University of Texas reported that satellite measurements had revealed that the Earth's tilt is being affected by the shift in mass caused by the melting of ice covering Greenland. The team found that around 15 years ago the Earth's axis began to move

east and then south. Earlier this year, researchers at NASA's Jet Propulsion Laboratory confirmed the effect, and added another cause: changes in the amount of water stored in the Earth's continents. Lower rainfall over Europe and Asia in recent years seems to be adding to the axial drift.

So is man-made global warming to blame for these changes? According to the JPL team, it's probably just part of the Earth's natural climatic rhythms.

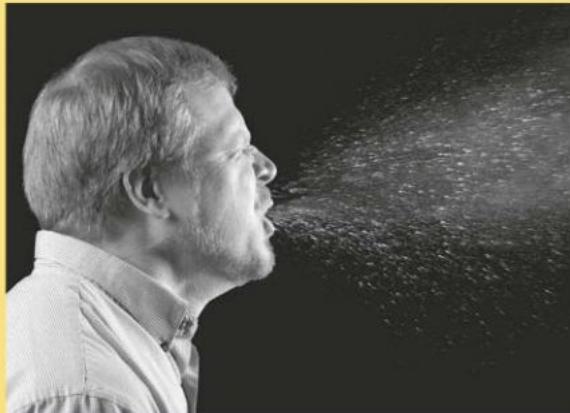
Either way, the effect isn't anything to lose sleep over: the recent shift amounts to less than one-millionth of the Earth's total tilt angle. RM



Strong winds and frosts caused ice to crack on Siberia's Lake Baikal

How far do coughs and sneezes travel?

CHARLIE MACK, UCKFIELD



Given the number of infections that can travel through the air, it's horrible when someone coughs over us. But according to research by scientists at the Massachusetts Institute of Technology, it's not just the person next to us we should worry about: coughing spreads droplets as far as six metres, and sneezing as much as eight metres. These droplets stay suspended in the air for up to 10 minutes. **RM**

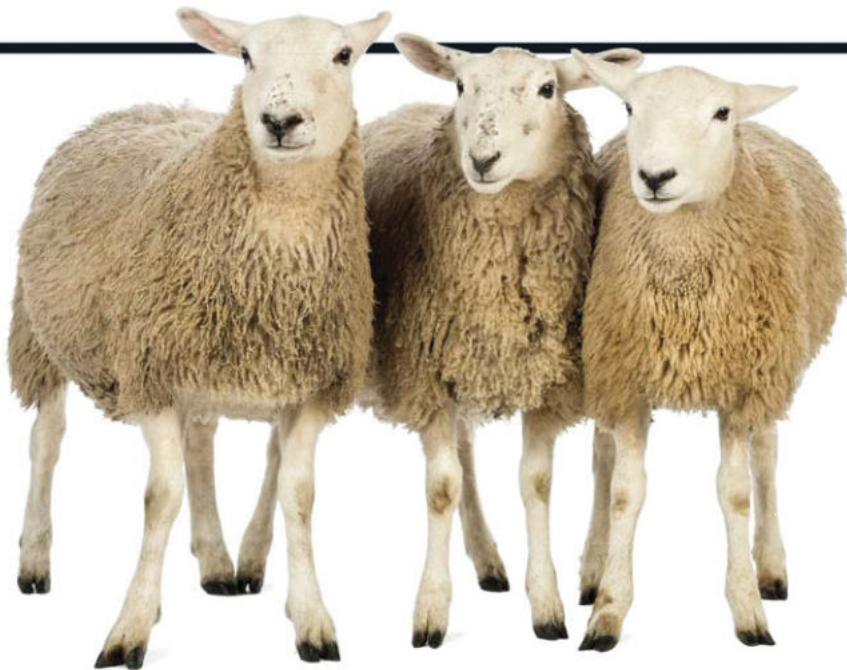
QUESTION OF THE MONTH

Could we use antimatter radiation to destroy cancer cells?

Eoin Walsh, Oxfordshire

Radiotherapy uses an X-ray beam to destroy tumours by dumping enough energy into their cells to break their DNA molecules. The problem is that the beam damages everything in its path, including healthy tissues, particularly if the tumour is deep in the body. Proton therapy, which uses protons instead of X-rays, is an improvement on this. As protons have mass, they decelerate as they travel through tissue and have the greatest ionising effect only once they've slowed down enough to interact with the

electrons in other atoms. This allows doctors to 'focus' the proton beam on the tumour, without affecting other tissues. Antiprotons (the antimatter version of protons) work even better because they don't just ionise the atoms they strike, they annihilate the protons in the nucleus of the tumour atoms. This releases gamma rays, which do even more damage to the tumour cells in a targeted way. Sadly, nowhere outside of CERN currently produces enough antiprotons to make this a feasible treatment. **WV**



Why do sheep all face the same way in a field?

DAVID WILSON, GLASGOW

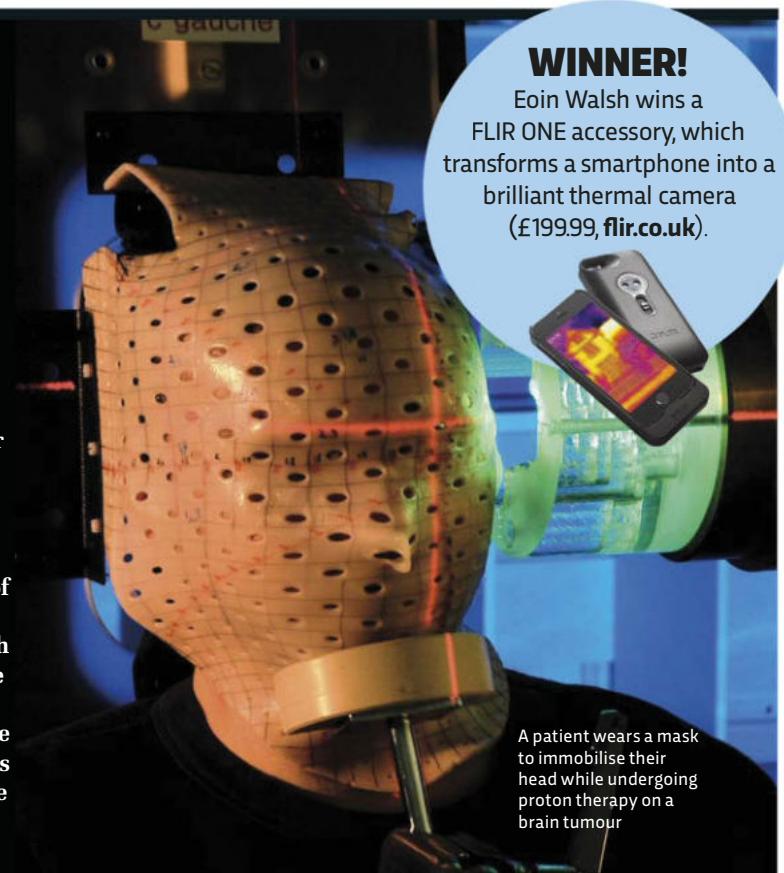
Sheep tend to stand with their backs to the wind when it is cold, but even on sunny days, cows, sheep – and even deer – all tend to face in the same direction.

Research looking at satellite images has shown that they

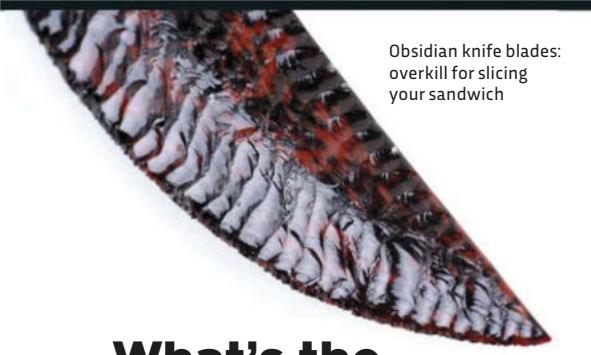
prefer to align themselves north to south. It's possible that they might be sensitive to the Earth's magnetic field, but how they can sense this, or why that might be useful, isn't currently understood. **WV**

WINNER!

Eoin Walsh wins a FLIR ONE accessory, which transforms a smartphone into a brilliant thermal camera (£199.99, flir.co.uk).



A patient wears a mask to immobilise their head while undergoing proton therapy on a brain tumour



Obsidian knife blades: overkill for slicing your sandwich

What's the sharpest knife in the world?

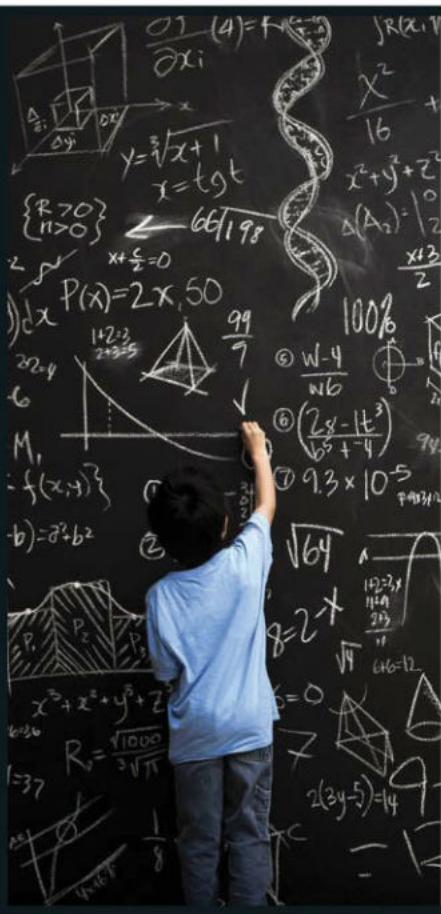
LIZZIE MYERS, ANDOVER

The thinnest blades are three nanometres wide at the edge – 10 times sharper than a razor blade. These are made by flaking a long, thin sliver from a core of obsidian (volcanic glass). They have been tested for use as surgical scalpels but aren't currently licensed for use on humans, since they could leave glass fragments in the wound. **lv**

What makes a child prodigy?

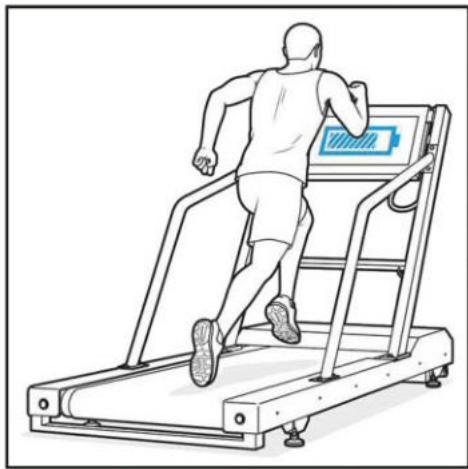
BILL STEINER, USA

Prodigies are defined by their childhood ability to perform at adult professional levels in a particular area. Some experts argue that prodigies benefit from years of intense, early practice, usually encouraged by ambitious parents. Others highlight prodigies' innate abilities: for example, a 2014 study assessed 18 child prodigies and found that what they all had in common was a heightened attention to detail and exceptional working memory (the ability to store and process information over short time periods). Prodigiousness seems to arise from a combination of this cognitive profile with what psychologist Ellen Winner describes as a "rage to master" their craft. **q**



THE THOUGHT EXPERIMENT

WHICH GENERATES MORE ELECTRICITY: RUNNING ON A TREADMILL OR WEARING SOLAR PANELS?



1. RUN FOR AN HOUR

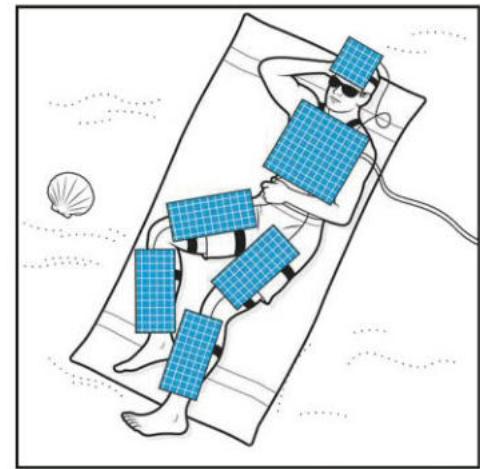
If you are reasonably fit, you can generate around 700W of electricity on a treadmill.

If you run on the treadmill for an hour a day, this would add up to 255kWh per year – or about 5 per cent of a typical UK household's consumption.



2. WEAR BODY PANELS

The human body's surface area is around 1.8m², but wearing more than 1m² of solar panels on your clothes would make it too hard to move. Only half of this area would be facing the Sun at a time, giving an effective generating area of 0.5m².



3. TAKE A POWER NAP

Solar panels typically generate 150W per square metre in good sunshine. If you are outside from dawn until dusk every single day in the UK, this would generate 53kWh per year. If all you do is sunbathe for an hour at midday, it will be more like 10kWh.

Why does sunshine make me tired?

LUKE DAVISON, EAST GRINSTEAD

If you spend time in the sunshine, your body must expend energy to prevent you from overheating. One way it does this is to sweat, which leads to lethargy and dehydration if you don't drink enough. The more you exert yourself, the more work your body has to do to control your temperature, which makes

everything feel like an effort. The cold makes people feel tired for the opposite reason, as the body must consume energy to stay warm, including through shivering. Bear in mind, though, the Sun doesn't only make you feel tired. By influencing your circadian rhythm – the body's internal clock – it also helps you get up in the morning. **q**



TOP 10

HEAVIEST LAND CARNIVORES



1. Walrus*

Weight: 1,200kg

Diet: shellfish, occasionally seals

*Walruses spend a third of their lives on land or ice.



2. Polar bear

Weight: 700kg

Diet: ringed and bearded seals



3. Brown bear

Weight: 680kg

Diet: salmon, berries, seaweed



4. Siberian tiger

Weight: 318kg

Diet: deer, pigs

How do we know the Universe hasn't always existed?

PETE SEARS, AUSTRALIA

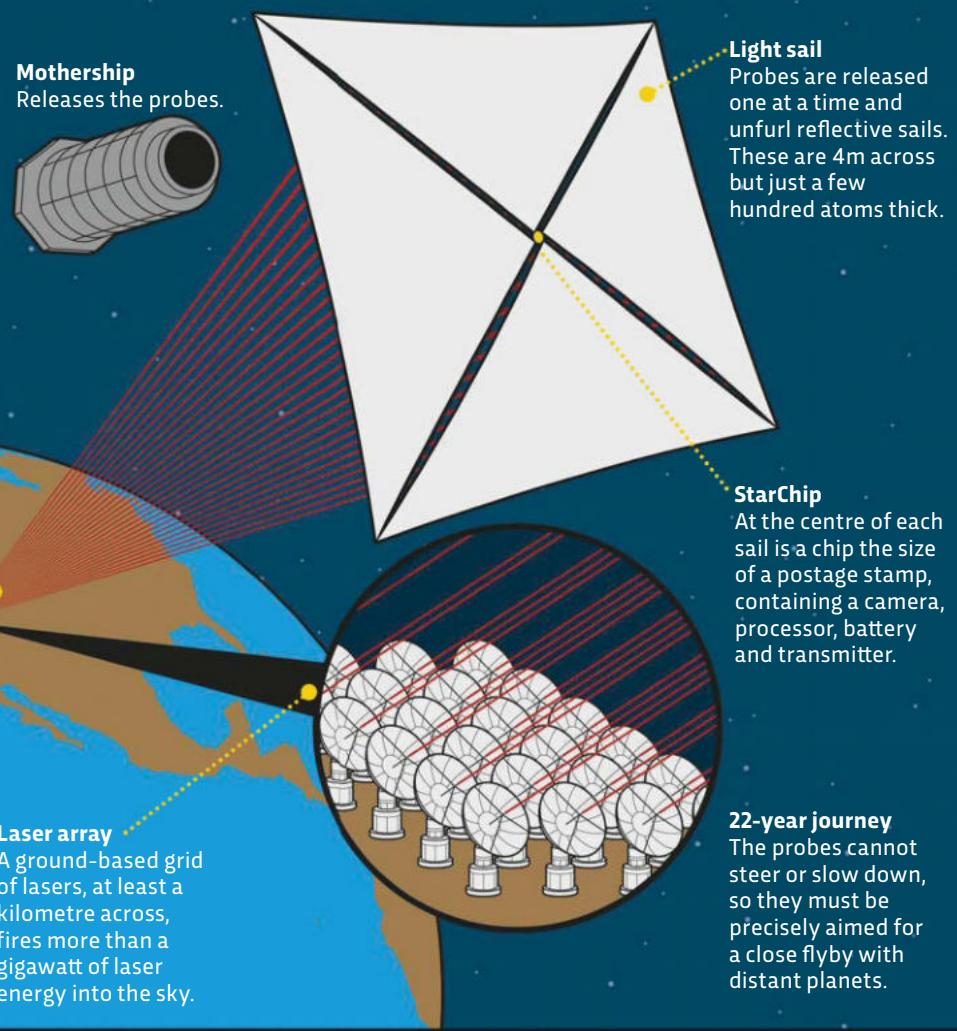


There's a wealth of evidence that the Universe began in a Big Bang around 14 billion years ago. We can see distant galaxies racing away from each other, and the space around them is filled with cosmic radiation whose intensity and spread are consistent with that expected from the aftermath of the Big Bang. But none of this rules out the possibility that there was another universe before ours.

According to some theorists, when Einstein's theory of gravity is combined with quantum theory, the Big Bang could really be part of a Big Bounce, in which the collapse of a previous – and perhaps very different – universe is followed by the creation of our own. While speculative, these theories do at least resolve the otherwise tricky question of what existed before the Big Bang. **RM**

BREAKTHROUGH STARSHOT

It would take standard rockets 100,000 years to reach the Solar System's nearest star, Alpha Centauri. Breakthrough Starshot hopes to do it in 22. A spacecraft carrying 1,000 ultralight probes, weighing 10g each, would be launched into Earth orbit. The 'mothership' would release the tiny probes one at a time, which would then ride the beams of a colossal ground-based laser array. The project has received £70m from entrepreneur Yuri Milner, and backing from Prof Stephen Hawking.



5. African lion

Weight: 250kg
Diet: wildebeest, zebra, carrion



6. Burmese python*

Weight: 183kg
Diet: rats, deer, goats

*Heaviest recorded specimen



7. Jaguar

Weight: 158kg
Diet: caiman, deer, capybaras



8. Green anaconda

Weight: 97.5kg
Diet: fish, birds, deer



9. Spotted hyena

Weight: 90kg
Diet: wildebeest, zebra



10. Grey wolf

Weight: 80kg
Diet: moose, deer

Do all cats like catnip?

RACHEL COSS, LITTLEHAMPTON



The active ingredient in catnip is nepetalactone. This is a volatile oil, which binds to the sensory receptors in a cat's nose that are normally used to detect sexual pheromones. This creates a 'high' that lasts for about 10 minutes and is perfectly non-addictive and harmless to the cat. But about a quarter of cats lack the gene that allows them to enjoy catnip, and kittens under eight weeks seem to be actively repelled by it. **lv**

Could you survive on vitamin pills and water alone?

DEREK SMYTH, BY EMAIL

Definitely not. Vitamins are micronutrients. Your body needs them in small quantities to ensure optimum health, but they don't comprise the bulk of the food you need to survive. For that you need the correct mixture of carbohydrates, fats and proteins. A multivitamin tablet does normally contain a small amount of starch, and some protein in the form of brewer's

yeast. But to get enough calories to survive, you would need to eat a couple of thousand tablets per day. And if you tried doing that, the huge dose of vitamin A would cause liver failure, long before you noticed malnutrition from the missing fatty acids. If you stuck to the recommended dose of one or two tablets per day, you would simply starve to death in about six weeks. **lv**



IN NUMBERS

<6 per cent

The proportion of American alligator attacks that are fatal.

1/3

The fraction of the world's population who can't see the Milky Way.

1

million

The number of clownfish taken from the wild each year.

Could we send a robotic probe to Earth's core?

MADDIE FRASER, LONDON

It's 6,371km (3,959 miles) to the centre of the Earth and the deepest hole ever drilled (the Kola Superdeep Borehole) was only 12km (7.5 miles) deep. We could try sending a robot probe, but it would not get very far. The pressure in the Earth's core is more than 3,000 times the pressure at the bottom of our deepest ocean. The temperature is more than 5,000°C. Your poor little tunnelling machine would be crushed to a pea and then cooked to a bubble of gas long before it could get anywhere near Earth's core. **pb**





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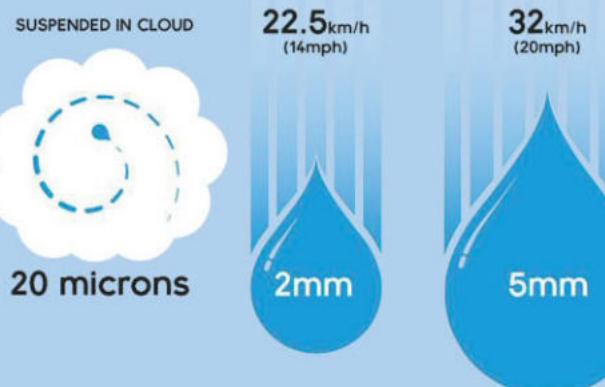
Why do we roll our eyes when we're exasperated?

GEORGE BRIGNAL, CAMBRIDGE

Today, eye-rolling is frequently used as signal of covert rebellion: think of the teenager who submits to a parental reprimand while looking skyward for the benefit of her friends. But it wasn't always so – an analysis of mentions of eye-rolling in literature shows that the modern meaning only emerged in recent decades. In Shakespeare, for example, eye-rolling is associated with lust. Unfortunately, we don't know much more than that – psychologists have spent much time studying smiles, frowns and sneers, but they've mostly neglected the eye roll. One exception: a study published last year found that women frequently perform eye rolls when exposed to sexist jokes. **q**

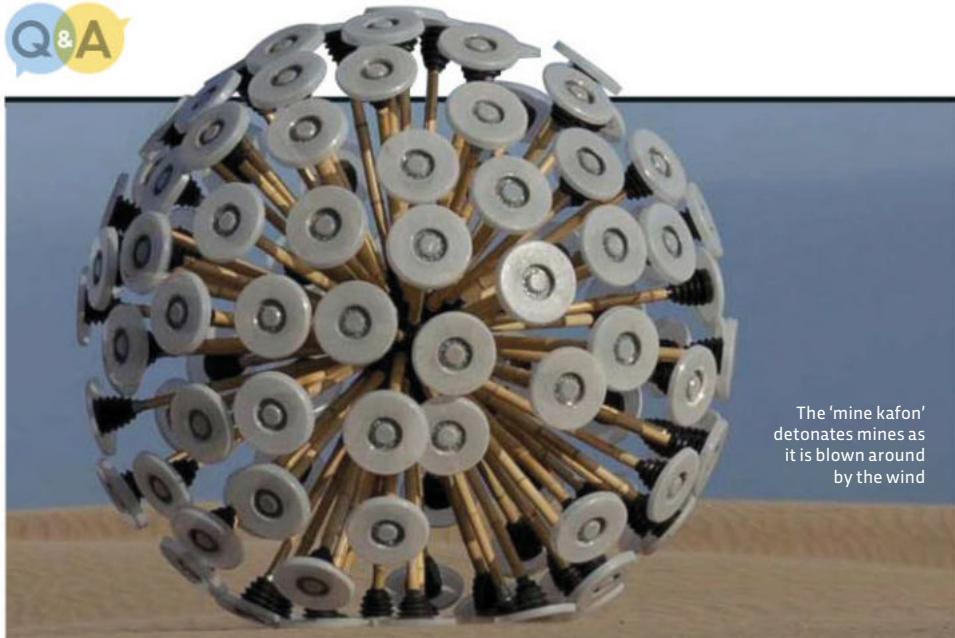
How fast does rain fall?

RANDALL BARFIELD, US



The terminal velocity of a raindrop depends on its size. The water droplets in clouds are only around 20 microns across and fall at only 1cm per second or so. This is normally balanced by updraughts, so the cloud

stays in the sky. The droplets in a light shower are 100 times larger and fall at 6.5m/s or about 22.5km/h (14mph). The largest possible raindrops are 5mm across and hit the ground at 32km/h (20mph). **lv**



The 'mine kafon' detonates mines as it is blown around by the wind

Could drones be used to detect landmines?

PANOS AUGUSTITHIS, GREECE

It's very tricky to detect mines because they are designed to be hidden from view. An unmanned drone is being developed for this purpose in the UK by Sir Bobby Charlton's charity Find a Better Way. It aims to spot chemicals leaching from mines using its hyperspectral imaging of plant foliage.

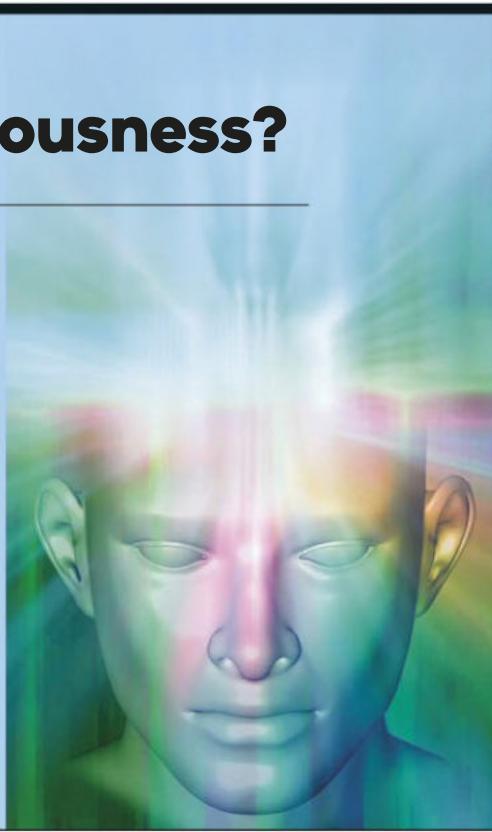
However, most devices aim to safely detonate the landmines. An unusual example is the 'mine kafon'. This giant biodegradable ball of bamboo spines is designed to be blown by the wind across a minefield, detonating mines that its spines touch, while its onboard GPS records where it has travelled. **PB**

NO EASY ANSWER

What is consciousness?

SARA NETSKAR, NORWAY

There are three main schools of thought. The higher order theory says that consciousness is the brain looking at its own activity. The brain is a machine that constructs simulations of how the outside world works and consciousness is the brain's simulation of itself. The global workspace theories argue that consciousness is something that happens when different parts of the brain connect together to share information. And the biological theories look for a specific process or structure within the brain that creates consciousness; such as the oscillations of the signals between neurons that appear in the brain scans of conscious subjects. **LW**



WHAT CONNECTS...

...SEASHELLS AND BYZANTINE EMPERORS?

1.



The mollusc *Bolinus brandaris* is a predatory sea snail that's found in the Mediterranean.

It secretes the antimicrobial substance dibromoindigotin from a gland.

2.



The secretion can be 'milked' from the snails and used as dye. In daylight, the dye degrades from purple to blue, but the ancient Phoenicians first found a way to lock in the purple hue.

3.



The dye became known as 'Tyrian purple' and actually became

brighter over time. It took over 10,000 snails to make a gram of dye, so it was fabulously expensive.

4.



The imperial court of the Byzantine Empire passed laws restricting the use of the dye to the royal family only. The emperor's children were 'porphyrogenitus', which means 'born to the purple'.

WHAT IS THIS?



Extreme insect

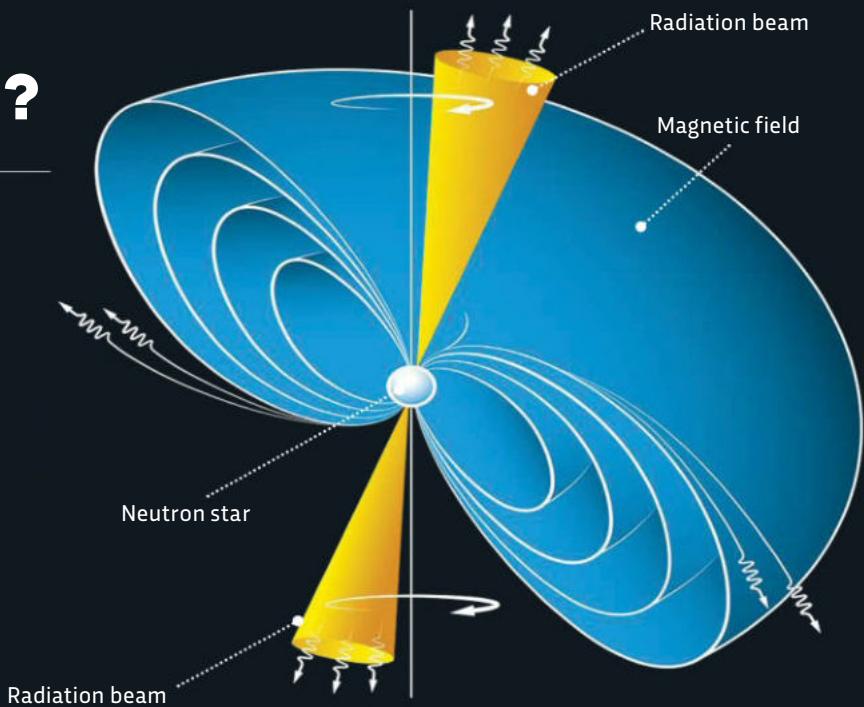
This leggy critter, measuring up at an impressive 62.4cm, was recently crowned the longest insect in the world. It's so big that it would not fit on these two pages of the magazine!

Dubbed *Phryganistria chinensis zhao*, the insect was discovered on a mountain in the Guangxi region in southern China by scientist Zhao Li. Li took it back to the Insect Museum of West China, where it laid six eggs. When the babies hatched, they measured 26cm.

What starts a pulsar spinning?

ROD DEAN, DEVON

Ultimately, the spin of a pulsar is derived from the spin of the star from which it formed. And the spin of the original star is a consequence of the spin of the gas cloud from which it formed. Since angular momentum is conserved, a decrease in an object's radius will speed up the rate of rotation. And since pulsars are formed by the collapse of very large stars into very small, dense objects, the increase in spin rate for pulsars is enormous. Some of the fastest spinning pulsars ('millisecond pulsars') have also gained speed by accreting material from nearby companions. **AG**



HEAD TO HEAD



CHOCOLATE

240kcal

ENERGY PER BAR/PACKET

169kcal

530kcal

ENERGY PER 100G

520kcal

56g

SUGAR PER 100G

2.6g

18.5g

SATURATED FAT PER 100G

2.5g

0.23g

SALT PER 100G

1.22g



CRISPS



CHOCOLATE	CRISPS
240kcal	ENERGY PER BAR/PACKET
530kcal	ENERGY PER 100G
56g	SUGAR PER 100G
18.5g	SATURATED FAT PER 100G
0.23g	SALT PER 100G

Both snacks have roughly the same number of calories by weight, but the calories in milk chocolate come from sugar and saturated fat, whereas crisps are mainly starch and

monounsaturated fat. A packet of crisps also weighs less than even a small bar of Dairy Milk. Apart from the salt, crisps are a bit healthier than chocolate. **LV**

Why does paper make so much noise when crumpled?

RONALD PIRANI, US



It doesn't take much energy to bend paper, but crumpling it demands injecting so much energy into the fibrous structure of the paper that it's not merely bent but is permanently deformed, creating sharp creases. Researchers at the University of Chicago showed that such creases form suddenly, and release some of the energy injected in a surprisingly loud burst of noise. **RM**

Does cryotherapy work?

RICK WILSON, SHEFFIELD

Probably not. Whole body cryotherapy involves exposing the entire body to dry air temperatures of -100°C for two to four minutes. There have been a few studies that found it helps relieve muscle soreness after exercise, but a 2015 Cochrane review concluded that these were not well-designed studies and the evidence was "of very low quality". The evidence that it boosts the immune system is even weaker. **rw**



£9 billion

The potential cost of people pulling 'sickies' in the UK each year.

1

metre

The amount by which the Dead Sea's surface level is dropping each year.

Is a black hole really a hole?

CHRISTINE BINGHAM, NOTTINGHAMSHIRE

No, a black hole is not really a hole at all. A black hole is an object just like any other, except that it is extremely dense. This gives it such a high gravitational field that nothing, not even light, can escape. Because no light escapes a black hole, it is invisible – or 'black' – although they can be detected by their effect on the material around them. The term 'hole' was used because whatever falls 'into' a black hole is trapped forever. Science fiction often depicts black holes as portals between different parts of the Universe, different times or different universes

altogether. This may be why it is often misconstrued that black holes are 'holes' in space-time. This concept isn't entirely fictional, however. In 1935, Albert Einstein and Nathan Rosen proposed 'wormholes' through space-time, which could provide a means of traversing large distances instantaneously. But a naturally occurring black hole doesn't form a wormhole by default. In fact, there are doubts they could occur naturally at all, that they would remain stable for more than a fraction of a second or that they would be anything bigger than vanishingly small. **ac**

NEXT ISSUE:

Can viruses infect bacteria?
Why are cats' tongues rough?
How do we get superhuman strength in a crisis?

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ROBIN INCE ON... HUMAN-ANIMAL RELATIONS

"WE ARE BROUGHT UP WITH TALKING HIPPY BEARS. IT'S NO WONDER WE ANTHROPOMORPHISE"

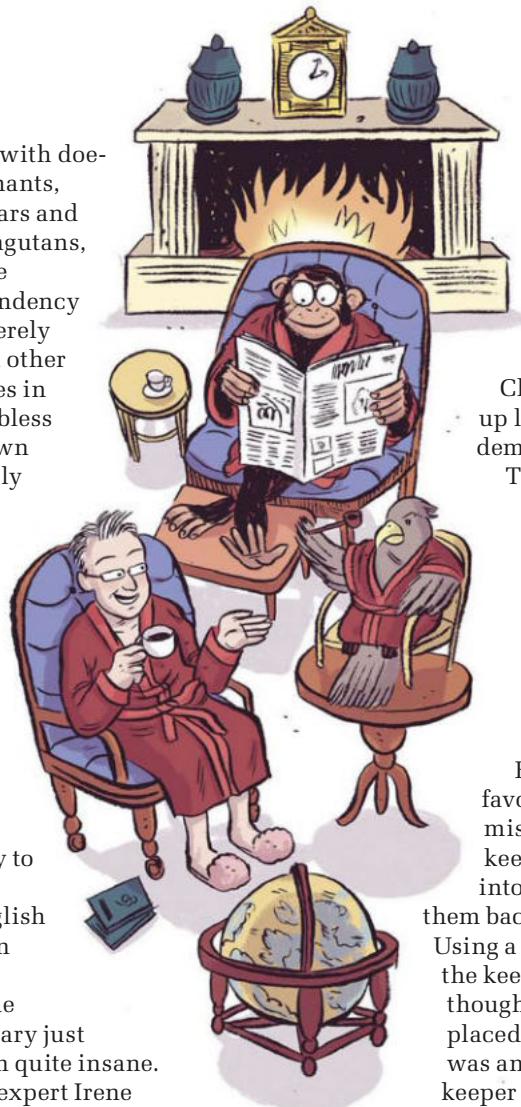
We are brought up with doe-eyed flying elephants, talking hippy bears and scat-singing orangutans, so it's no surprise that we have a tendency to anthropomorphise. We don't merely empathise with our own, but with other species too. We see our own visages in the faces of our dogs and cats. We bless or curse other animals with our own emotional palette. But can we really make friends with other species?

The slow loris is a good example of our mistaken projections. We interpret the big-eyed creature's outstretched arms while being tickled as a sign of joy. Actually, it's scared, and it's stretching out to try to gather the venom that's found in its elbow patch.

How can we overcome these communication breakdowns? Sometimes, like Dr Dolittle, we try to talk to the animals.

The most fluent non-human English speaker I know is my dad's African grey parrot. It pipes up in the background when I'm giving phone interviews, but rations its vocabulary just enough for listeners to believe I am quite insane. The research of animal cognition expert Irene Pepperberg demonstrates that this is not just mimicry. Her parrot subject, Alex, would say "wanna go back" when tired of being tested, would accept no substitute if he asked for a banana, and would apologise when appropriate. Pepperberg's work changed our view of the intellectual capabilities of birds.

The intelligence of dolphins has been admired for considerably longer. John C Lilly was a US medic and psychoanalyst who believed that a dolphin could be taught English. His assistant, Margaret Howe, spent 10 weeks living with Peter, a bottlenose dolphin. The experiment was a failure – Peter appeared to fall in



love with Margaret. Once the funding ran out, Peter was put in an isolated tank in Miami and, seemingly depressed, he sank to the bottom and made no effort to breathe. Some describe this as suicide.

Other 'humanising' experiments have had similarly questionable results.

Perhaps the most famous case is Nim Chimpsky – a chimpanzee who was brought up like a human child in the hope of demonstrating communication between species.

The experiment was terminated when Nim attacked one of his carers. He was put back in a primate enclosure and, unsurprisingly, he struggled to adapt, never recovering from his upbringing as an ape-child.

In the cases of Nim and Peter, perhaps we learnt more about our own limits of empathy than we learnt about the animals themselves.

But it's not all doom and gloom. My favourite story involving an interspecies misunderstanding occurred in Bronx Zoo. A keeper accidentally dropped a roll of \$10 notes into a silverback gorilla's enclosure. Could he get them back by teaching the gorilla how to barter?

Using a mixture of enticing fruit and complex mime, the keeper tried to negotiate a swap. But just as he thought he was getting through, the silverback placed the roll of notes in its mouth and ate them. It was another communication breakdown. While the keeper thought he was expressing, "hey, let's swap this delicious food for that boring wad of paper", the gorilla translated it as, "your paw contains things as delicious as this fruit. Gorge yourself."

So perhaps we should just learn to accept our differences. Maybe John Carradine's elderly werewolf in *The Howling* was right all along. Confronting the kindly, and soon to be eaten, doctor who attempted to domesticate the lycanthropes, he said, "you can't tame what's meant to be wild, doc."

And maybe that's really true of humans too. I'd better go and put my son back in his cage before nightfall... 

Robin Ince is a comedian and writer who presents, with Prof Brian Cox, the BBC Radio 4 series *The Infinite Monkey Cage*.

NEXT ISSUE: SLEEP SCIENCE



For more on the power of music, listen to a recent episode of *The Infinite Monkey Cage* at bbc.in/292y0cN



TUNING IN

Music reduces adrenaline and cortisol levels in the body, while increasing oxytocin. This can improve our mood, beat stress and help us exercise harder.



UNDERSTAND THE POWER OF MUSIC

What we choose to listen to can have a profound effect on our emotions and behaviour

WORDS: DR JOHN POWELL

Music is an integral part of our lives. We carry it in our pockets and blast it from the rooftops. It's the stuff that memories are made of, soundtracking our weddings, funerals and first kisses. But it has an even greater effect than you might imagine, from alleviating stress and depression to helping us bond with others and boosting IQ scores. Over the following pages, we delve into the surprising psychology of music.

Does music really have the power to affect our well-being?

Your body contains its own 'pharmacy' for dispensing an array of chemicals to help you respond to different situations: calming you down when you need to sleep, or putting you on alert if you're in danger.

If your pharmaceutical system is working properly, the correct chemicals will be dispensed at the appropriate times. If a dog starts chasing you, for example, your internal pharmacist will hand out a shot of adrenaline and a dose of cortisol. The adrenaline will

get you ready to run or fight by increasing the oxygen supply to your muscles, directing more blood to your heart and lungs, and releasing extra glucose into your system. The cortisol reaction will further amplify the adrenaline's effects, increasing your blood sugar levels and concentrating energy supplies to your arms and legs. These effects are useful during short-lived 'fight-or-flight' events, but are not good for you over an extended period of time.

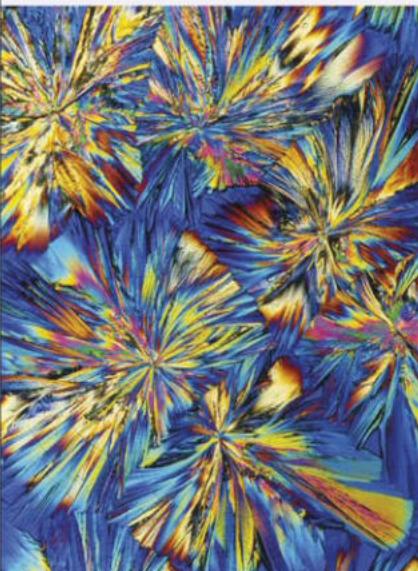
If you lead a busy, stressed life, you might become depressed or physically rundown because your inner pharmacist is constantly doling out adrenaline and cortisol – even in non-threatening situations. This is where music can help. Listening to calming music has been shown to diminish the adrenaline and cortisol levels in the bloodstream and therefore reduce stress. Researchers at the University of Toronto have even shown that this is true of distressed babies. On top of this, the fact that music is

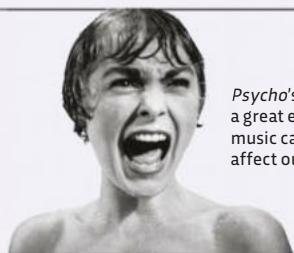
pleasurable tells the internal pharmacist to start handing out chemicals like dopamine and serotonin, which will improve your mood and help to banish the stress and depression.

How else can music help?

Music has also been shown to cure insomnia. In a study involving young adult insomniacs in Budapest in 2007, over 80 per cent of the participants became better sleepers after three weeks of

Crystals of adrenaline, as seen through a light microscope





Psycho's shower scene is a great example of how music can powerfully affect our emotions

● listening to classical music at bedtime. In a similar investigation involving Taiwanese insomniacs aged over 60, half of the participants were transformed into good sleepers within a few weeks.

It normally takes an adult between 10 and 35 minutes to drop off to sleep. If you're having trouble drifting off, you could make your own playlist. Choose about 45 minutes of slow, calming music, and make sure the final track fades out gradually, otherwise the abrupt silence at the end will wake you up (one of our survival instincts is to wake up if things go suddenly quiet).

How does music manipulate our emotions?

The world of film offers obvious examples of music manipulating our emotions. If the action on the screen is emotionally neutral (a woman walking down a street) the music can tip us off that something frightening or happy is about to happen. If the director wants to make you jump with fright, a sudden loud noise (or musical sound) is very effective in triggering your fight-or-flight response, which will flood your system with adrenaline and cortisol. Your brain subconsciously assumes that you're in danger because we have evolved to associate any unexpected noise (even music) with a possible threat. This is why the 'eee! eee! eee!' shower scene music in *Psycho* is so terrifying.

The job of a film's music composer is to manipulate your emotions without making the music too obtrusive. One effective way of amplifying the emotional impact of a visual event is to precede the climax of the scene with inappropriate music. If a father is searching

for his daughter, we feel much more relief when she's found safe and sound if the searching scene was accompanied by creepy, menacing music. Similarly, we are a lot more horrified if, after a search accompanied by cheerful music, we are presented with a bloodstained body and a loud, anguished chord.

Does it help to listen to music while exercising?

Yes – gym-based studies have shown that music encourages people to increase their pace to match the pulse of the music, and the pleasure of listening helps them to stay on the equipment for longer. Music also alleviates boredom and helps runners to focus their attention away from pain or discomfort.

In fact, the effect is so great that the USA Track and Field's competition rules ban runners from using portable listening devices if awards or prizes are involved. And, of course, it's never a good idea to be wearing headphones if you're running close to busy roads.

How about listening to music while working?

The possible link between music and concentration has been the subject of much research – it's of interest to everyone from call centre managers to students trying to finish an essay.

These investigations have shown that music can help if the alternative sound is a distracting noise. If you're trying to finish that report in a busy cafe, then music through headphones will help keep you focused. If, on the other hand, you're working in a quiet environment, the music itself will be a distraction. Part of your brainpower will be



Mozart can improve your results on IQ tests – but other music can too

JARGON BUSTER

Adrenaline

This chemical triggers the body's fight or flight response. It causes your air passages to dilate so you can get more oxygen into your system, and directs blood to the major muscle groups.



Cortisol

This is another fight or flight chemical and backs up the adrenaline response. It also damps down your body's response to injuries (so you can keep running or fighting even when hurt).



Dopamine

This neurotransmitter is responsible for your ability to focus and get things done. It also acts as a 'good mood' chemical.



Neurotransmitter

These chemicals communicate information throughout your brain and body. They tell your heart to beat, they control muscles and senses, but also influence your mood.



Serotonin

A neurotransmitter that's involved in regulating appetite, sleep, memory and mood.



The Mozart effect

This is a controversial idea that suggests that listening to classical music can boost your intelligence or a child's mental development.

WHAT YOUR MUSIC SAYS ABOUT YOU

Would you rather relax to Rachmaninoff or rock out to the Ramones? According to psychologists at the University of Cambridge, your musical preferences can reveal a surprising amount about your personality

Take the test for yourself at musicaluniverse.org



Empathisers (Type E)

Have a strong interest in people's thoughts and emotions

Likely to listen to mellow music with low energy and sad emotions such as R&B and soft rock. Prefer unpretentious music like folk and country, and contemporary music such as electronica.



Example song:
All Of Me
Billie Holiday



Systemisers (Type S)

Have a strong interest in analysing rules and patterns

Likely to listen to more intense music, including hard rock, punk and metal. Also prefer music with depth and complexity such as avant-garde classical music and experimental jazz.



Example song:
God Save The Queen
Sex Pistols



Balanced (Type B)

Score relatively equally on empathy and systemising

Likely to listen to a broader range of different musical styles and genres than those people who are pure empathisers or systemisers.

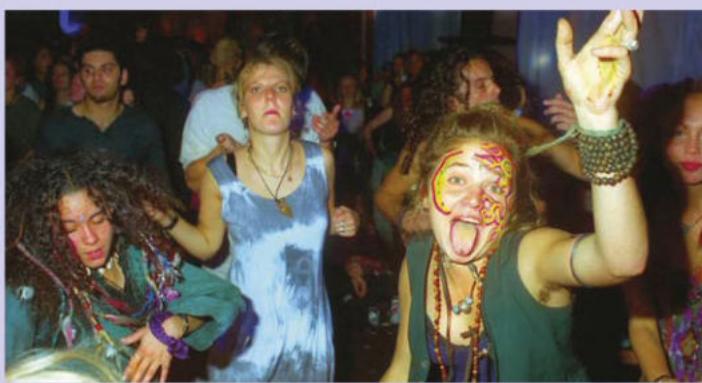


Example song:
Come To Daddy
Aphex Twin

WHAT WE STILL DON'T KNOW

1 WHAT CAUSES THE 'TINGLE FACTOR'

Many of us have a particular song or piece of music that gives us goosebumps or sends shivers down our spine, whether that's a Bach cantata, a pop anthem, or a piece of experimental electronica. But we haven't yet worked out how or why this happens. What's going on in the body to produce this physiological response? Is it the same mechanism in everyone? Brain scanning should reveal the answer to this musical mystery.



Even today, these people probably still insist that 90s rave music is the best genre. It's not because it was, it's because of psychology and sociology

2 WHAT GIVES US MUSICAL NOSTALGIA

Anyone over the age of 30 will tell you that their youth was the best time for music, pointing out that "all modern stuff is rubbish!" But why do we retain such a strong affinity for the music we loved in our late teens and early twenties? The reasons are probably rooted in sociology and psychology, and have very little to do with the actual music itself.

3 WHY OUR MUSICAL MEMORY IS SO GOOD

Most of us can remember the finer details of musical pieces we haven't heard for years. People who have suffered serious memory loss due to accidents or disease often retain their musical recollections, and these can even be effective in restoring speech in stroke patients who have lost the ability to speak. We know that music is processed in lots of different areas of the brain, so could this be why musical memories are able to survive local brain damage?

**In one tweet...**

Music is a global panacea. It reduces stress, increases happiness, helps us bond with others and can even be a form of pain relief.

● taken up processing the music, leaving less capacity for the work you're trying to do. Music with lyrics is particularly distracting.

The situation is a little different if you're performing a simple task such as ironing or washing up. In this case, you'll have plenty of spare mental capacity available, and the music will help keep you in a good mood and prevent you from getting bored, probably improving your performance on the task in hand.

Can music really affect our behaviour?

Yes. Take, for instance, the background music that's often played in shops and restaurants. This can have a surprisingly powerful influence on how we behave.

Working in the 1980s, US marketing professor Ronald Milliman discovered that slow, relaxing music in a restaurant actually makes you eat more slowly and increases the amount you spend on drinks during the meal. The tempo of the music also has an effect on how quickly you walk around a shop or supermarket – you tend to browse and buy more if the music is calming and relaxed.

Surprisingly, the choice of background music can even influence which items you buy. One test, carried out by psychologists at the University of Leicester in 1999, involved changing the background music near a display of German and French wines in a supermarket. The German wine sold twice as fast if stereotypically German music was playing, but when French accordion music was being piped out, the French wine was *five times* more popular than the German.



Exercising to music helps you forget discomfort

'Uncool' music, such as Barry Manilow's, can successfully deter teenagers



Other research in this area has shown that the correct choice of background music can increase the income of a shop or restaurant by 10 per cent – a surprisingly large effect for something that many of us barely notice.

Another indication of the power of background music is something known as the 'Manilow method'. In 2006, Sydney's city council was trying to work out how to disperse the groups of teenagers who were hanging out in the shopping malls. Simply asking them to 'move on' had no effect – but eventually someone had the idea of playing music that the teenagers would find embarrassingly uncool. Barry Manilow to the rescue! By the time a few tracks of his greatest hits had filtered through the public

address system, the teenagers had wandered off to find somewhere cooler to hang out.

Why did music evolve in the first place?

Music is ancient and extends throughout all societies around the world, so it probably has links to the survival of our species. As any football fan will tell you, communal singing can help form a more cohesive social group. This bonding effect is a strong contender for why music exists – in prehistoric times, groups who sang together would protect each other more tenaciously from predators or enemies.

What's more, music has been found to aid the release of the hormone oxytocin. This hormone is also released during breastfeeding and sexual intercourse, and may have a powerful bonding effect.

EXPLAIN IT TO A FRIEND

1 IT'S A NATURAL DRUG

Music can help to control the release of certain chemicals in your brain and blood supply. Stressed people often have too much adrenaline and cortisol in their system, so they are perpetually in a fight-or-flight mode. Music inhibits the release of these substances and encourages the release of pleasure-related chemicals such as dopamine and serotonin.

2 IT ALTERS OUR BEHAVIOUR

Background music can have a surprisingly large effect on your behaviour. Slow music makes you walk more slowly in shops, eat more slowly in restaurants and drink more with your meal. Supermarket music can even persuade you to buy particular products by suggesting a certain country or mood.

3 IT HELPS US BOND

Music is ancient and exists across all of the world's cultures, so it's probably linked to the survival of the human race. One Darwinian reason for the existence of music is that it helps groups of people (from families to rugby crowds) bond with each other. Bonded groups collaborate more closely and therefore have a higher chance of survival.



As any footy fan can testify, communal singing strengthens social bonds in the group

Psychologist Raymond MacDonald found that pain is more bearable if you can listen to your favourite music



Where's the most unlikely place that music is used?

Forget popping a paracetamol – music has also found an unlikely use as a form of pain relief.

One of the experiments that researchers use to test people's responses to pain involves asking subjects to keep their hands in freezing cold water for as long as possible. Psychologists Laura Mitchell and Raymond MacDonald have found that listening to music helps people to stand the pain for longer – and is particularly effective if the subjects choose the music themselves. This choice gave the participants a feeling of empowerment, which helped them to cope with discomfort for longer.

The concept of pain reduction through empowerment has also been shown to reduce discomfort during dental treatment. The patients felt less pain if they chose the music – especially if they were given a handheld volume controller. Intriguingly, the best results happened when the patient was specifically *told* that their control over the music would reduce the pain.

Does music really have the power to make us more intelligent?

Back in 1993, US psychologist Dr Frances Rauscher and her colleagues published a paper which gave birth to the so-called 'Mozart effect'. In this study, students were given a spatial reasoning IQ test, before which they had either sat in silence for 10 minutes, listened to relaxation instructions, or heard a Mozart piano piece. The researchers found that those who tuned in to the piano piece had noticeably higher scores than the other two groups.

The implication that listening to Mozart's music makes you more intelligent was widely covered in the press, and soon the music industry was generating Mozart CDs aimed at improving the IQs of everyone from babies to pensioners.

Psychologists set to work investigating whether the Mozart effect really exists, and by 2010 it was concluded that it did – but it had nothing to do with Mozart. Various psychologists, including Prof E Glenn Schellenberg and his team at the University of Toronto, have proved that your score in an IQ test can be improved simply by listening to any stimulating music you enjoy (Schubert and Blur worked just as well as Mozart). A similar result could even be achieved by listening to a Stephen King short story.

The effect works by raising the level of a neurotransmitter in your brain called norepinephrine, which increases alertness. On top of this, enjoyable music boosts dopamine, helping put you in a buoyant and confident mood.

So, the next time you're about to take an exam, try listening to 10 minutes of your favourite upbeat music before you go in – but wear your lucky socks, too, just in case.

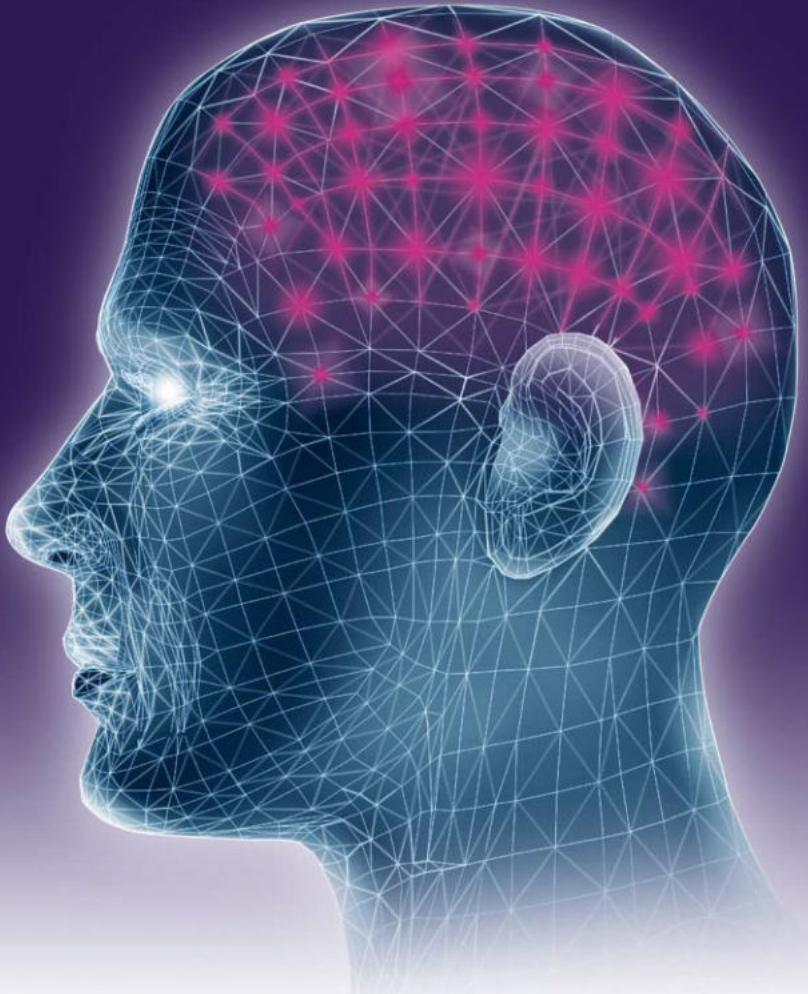
Dr John Powell is a scientist, classically trained composer and author of *Why We Love Music* and *How Music Works*.

DISCOVER MORE

Listen to a *Music Matters* programme that explores how music can manipulate and control us at bbc.in/1jb8BOR

NEXT MONTH: HOW DO WE KNOW THAT THE LOCH NESS MONSTER DOESN'T EXIST?

Feed your mind

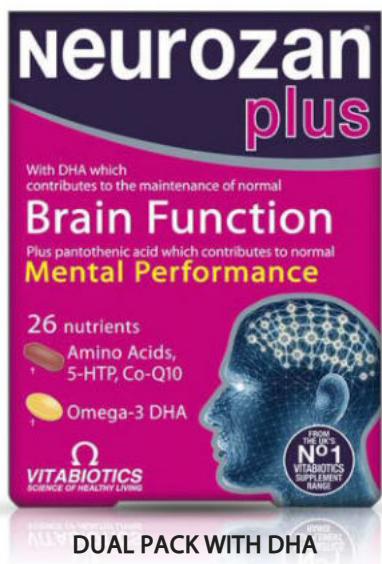


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[†]A beneficial effect is obtained with a daily intake of 250mg DHA.
*Nielsen GB ScanTrack Total Coverage Value Sales 52 w/e 25th April 2015.



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VITABIOTICS
SCIENCE OF HEALTHY LIVING

THE NUMBER GAMES

GIVE YOUR BRAIN A WORKOUT

AUGUST 2016

BY MATT PARKER

Welcome to our new number puzzle column!

Upon discovering I am a mathematician, many people feel the need to tell me how much they disliked maths at school. But for others, those same lessons were the beginning of a love affair with solving problems. Once you experience the high of successfully

working through a difficult puzzle, you can be hooked for life.

If you find yourself in the first group, but occasional indulge in the odd bit of 'brain-training', let me see if I can win you over. And if you find yourself in the latter, welcome home. Each month

I will present the best new maths puzzles from around the world, and celebrate the occasional classic. I will be ably assisted by Katie Steckles, a modern master of puzzles. Should you have your own puzzle you would like us to include, do send it in!

GAME 1: JOINING THE DOTS

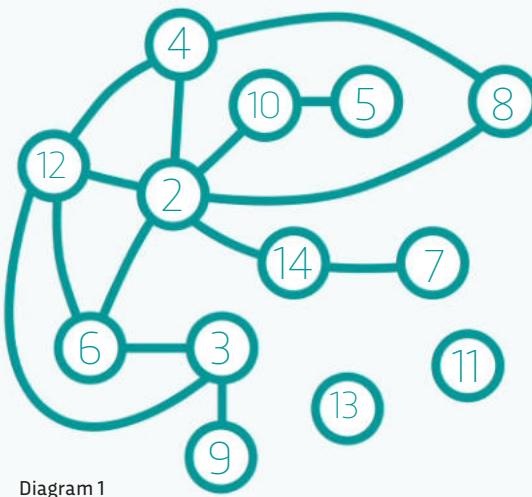
This is a deceptively simple puzzle which is infuriating because at some point it becomes impossible, but it does not have the decency to tell you when.

I was first shown this puzzle in a basement pub at the London MathsJam. The goal is simple: start writing numbers starting with 2 on a blank piece of paper: 2, 3, 4... and so on, but whenever a number you write is divisible by a number already on the page (other than 1), you need to link them with a line. And those lines are not allowed to cross.

The first line you need to join is linking 4 to 2. Then 6 needs to connect with both 2 and 3, while 8 joins 4 and 2. So far so easy. But then after a while you will number yourself into a corner. Already on my attempt I can see that wherever I write 15 I can't link it to both 3 and 5 (see diagram 1). Time to try again.

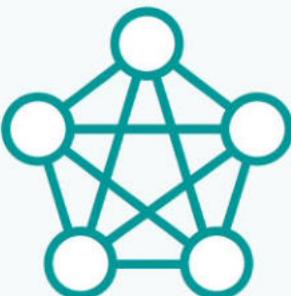
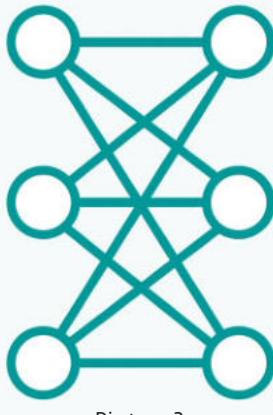
Often with this puzzle you will think you're stuck, but then you find a way to redraw the network to fit in the next number up. But eventually there will be a hard limit; there is a number which simply cannot be put on the network, but I'm not going to tell you what it is.

I will, however, equip you with the maths to work out when you can go no further. When you try to draw a network like this with no lines crossing, you are



looking for a 'planar network' – one which can be drawn on a flat plane, with no crossing points.

Mathematicians know that 'non-planar' networks contain one of two sub-networks, a 'utility network' (diagram 2) or a 'complete five network' (diagram 3). If you can spot one of these patterns – albeit without the lines crossing it – then you know it is impossible to draw flat without lines crossing. If you can't find one, then there is still a way to draw it.

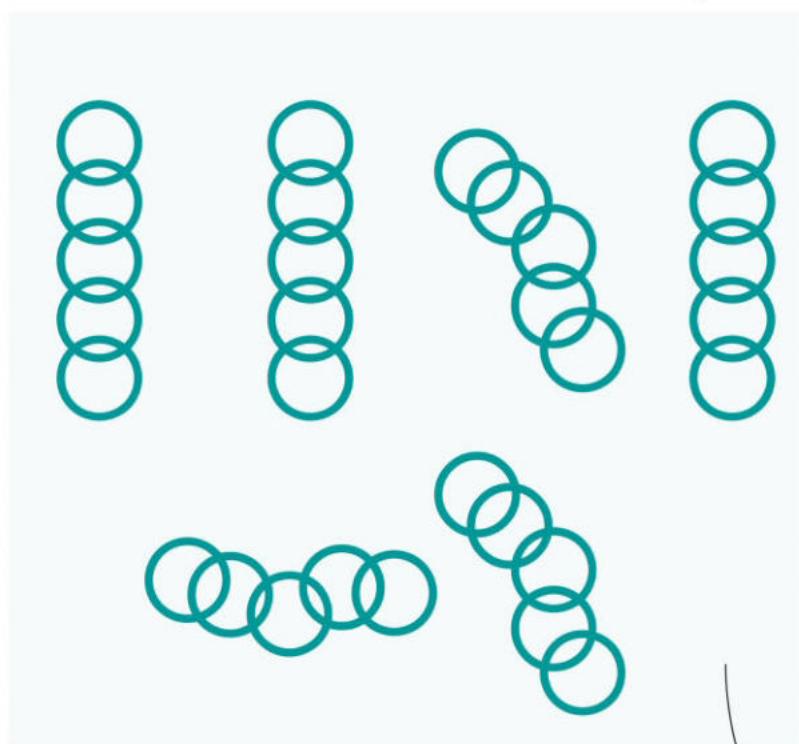


GAME 2: HIGHLY DIVISIBLE

Can you find the smallest number that is divisible by all of the digits 1 through 9? Multiplying $1 \times 2 \times 3 \times \dots \times 9$ gives you 362,880 but that is inefficient. A much smaller number will do.

Should that prove too straightforward, see if you can find the smallest number which is a multiple of all the numbers from 1 to 19.

And once you have a system in place, you can find the solution for any run of numbers. If you fancy stress-testing it, the smallest number which is divisible by all numbers from 1 through to 99 is 69,720,375,229,712,477,164,533,808,935, 312,303,556,800.



DISCOVER MORE

WHAT IS MATHSJAM?

MathsJam is a chance for like-minded maths enthusiasts to get together in a pub and swap puzzles or interesting bits of maths over a drink. MathsJams currently take place on the second-to-last Tuesday of every month in over 30 cities around the world, as well as an annual conference every November. Matt splits his time between the London and Guildford MathsJams, and Katie runs the Manchester one. Visit mathsjam.com to find your closest gathering.

GAME 3: LINKED IN

Here is a puzzle sent to us by Robin Houston from Sheffield MathsJam. Like many puzzles, it involves a slightly convoluted premise: you have six lengths of chain, each five links long, and want to make them into a single loop using all 30 links.

Of course you do. I theorise there is a hypothetical Puzzlelandia where the contexts for puzzles are normal day-to-day situations; people always need to measure four litres of water when they only have three-litre and five-litre jugs, evil masterminds run wild placing different coloured hats on blindfolded people, trains really need to know when they're going to pass each other. And in that world you look at your six five-link chains and dream of the day you have a single 30-link one.

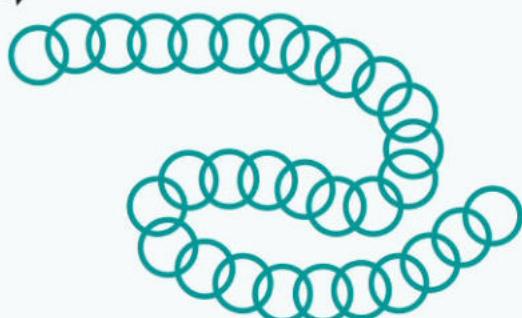
"A jeweller offers to do the job for £1.50, but the rival jeweller next door has a price list in the window: they charge 8p to break a link of chain, and 18p to fix a link. Can you get a better deal from the rival jeweller?"

It seems like there is decent competition for jewellers in Puzzlelandia. Enough for a jewellery district where one jeweller has gone with a set-price business model and their competitor has decided that transparent pricing will bring in more customers. You now have a choice of who to use.

Or rather: you don't. The question mark at the end of most puzzles is there for politeness. Of course it is going to be cheaper to go with the price-breakdown jeweller. It would be a lame puzzle otherwise. When you tackle a brain-teaser like this, you trust that it is not a practical joke where the answer is "no, it can't be done". Unless of course, the puzzle is about something which seems possible but isn't for interesting reasons...

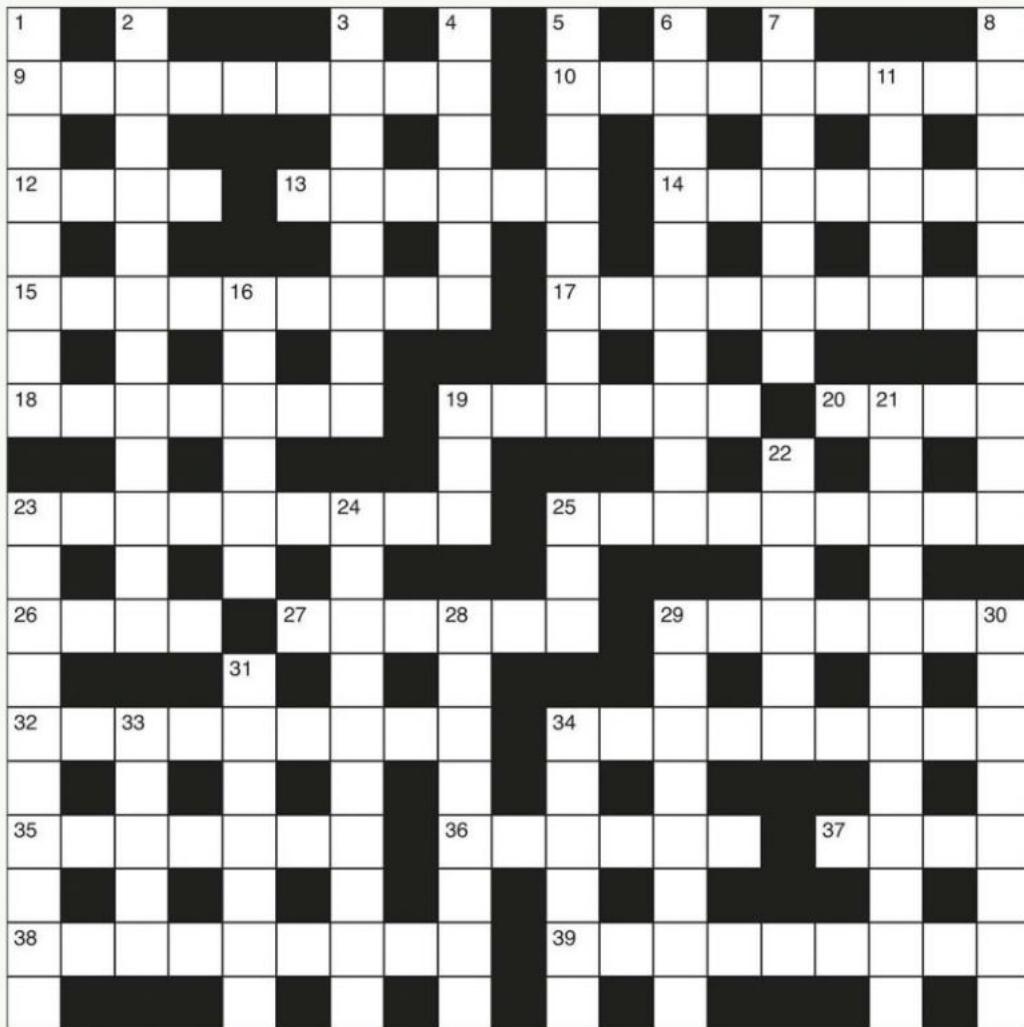
These types of chain-link puzzles have been around for a long time, dating back to at least 1897. In this case, the challenge is simple: find a combination of snips and joins such that the number of snips \times 8p added to the number of joins \times 18p is less than £1.50, a price no doubt chosen by the puzzle's author to be tantalisingly close to the best-case solution.

So make the six chains out of paperclips and start moving them around, or sketch them on a piece of paper, or just think about them really hard. Somehow there will be an interesting and rewarding way to solve this. Trust us.



THE BBC FOCUS CROSSWORD

BACK BY POPULAR DEMAND



ACROSS

9 Concerning bullock having guidance problem (9)
 10 He follows on to hit gold (9)
 12 Doctor has no problem getting satellite (4)
 13 Sausage used as mail (6)
 14 Performing a trio around province (7)
 15 Bird in the pan cooked with a bit of petroleum (9)
 17 Your hands deteriorate without water (9)
 18 Athlete depicted as Roman (7)
 19 Breaking bread with Jack on Homer's island (6)
 20 Metal oxide is contemptible (4)

23 Drag loony out of masculine study (9)
 25 Talk about posse using rifle (9)
 26 Get extra with a message (4)
 27 Inheritor gets iron from youngster (6)
 29 Two creatures provide waterproofing (7)
 32 New boom caught by fresh form of rule (9)
 34 Arranging to run the bar is a pain (9)
 35 Old equipment, new aim – Japanese art (7)
 36 That woman's lad turned into an announcer (6)
 37 Officers' room in a state (4)
 38 Establish a college (9)
 39 Way to go, having learnt the time (9)

DOWN

1 Soldier reputedly lacking underwear (8)
 2 Old problem of zones solved by new road in peace (5,7)
 3 Whale has strange accent containing vowels (8)
 4 Prioritising, get air-conditioning (6)
 5 Forcefully articulate, like a buccaneer (8)
 6 I poach boar out of fear (10)
 7 Energy bound to be heard in compound (7)
 8 Boilers not affected by a few stars (6,4)
 11 Controller takes over new school first (5)
 16 Rough girl to play with unruly mob (6)
 19 Confused a year with a shorter time (3)
 21 Airplane much affected by a type of code (12)
 22 Across junction, pursuing fictional lion (6)
 23 Any osmotic form of protein (10)
 24 Old game played without elementary particle (5,5)
 25 Copper right to get a dog (3)
 28 Insect to turn to energy storage device (8)
 29 Heir gets everything but an onion (8)
 30 Metal tent with snug construction (8)
 31 Relating to hip spies following small spasm (7)
 33 Composer's ecstasy (5)
 34 Satirist is hard on old people (6)

ANSWERS

Please visit bit.ly/TheNumberGames for the answers to this month's puzzles and crossword.

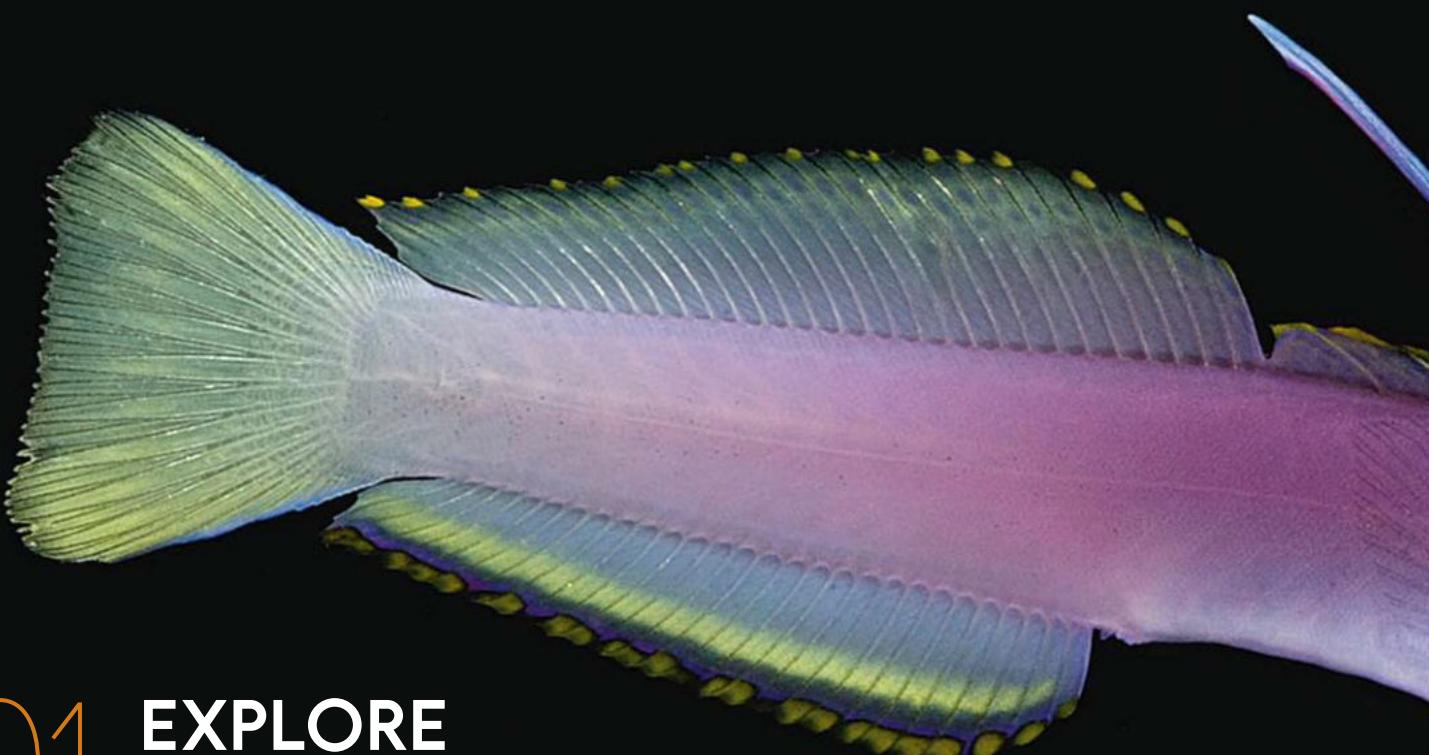
OUT THERE

WHAT WE CAN'T WAIT TO DO THIS MONTH

AUGUST 2016

EDITED BY JAMES LLOYD

The Helfrichi's firefish (below) inhabits waters down to 90m in the tropical western Pacific; the fangtooth (right) lives at depths of 300-5,300m in the world's oceans (image on this page is two separate pictures)



01

EXPLORE THE DEEP

LIFE IN
THE DARK BY
DANTÉ FENOLIO
IS OUT 29 JULY
 (£26, JOHNS HOPKINS
UNIVERSITY PRESS).

In the depths of the oceans, strange creatures lurk. A fangtooth fish flexes its tremendous jaws, while tropical firefishes display their glorious colours.

These are just some of the otherworldly creatures featured in *Life In The Dark*, a new book from zoologist and wildlife photographer Danté Fenolio. He's spent his career studying animals that live in darkness, whether that's at the bottoms of oceans, beneath the ground, or even inside other organisms.

In order to survive in the shadows, these life forms have evolved bioluminescence, unique body parts, and highly tuned senses. The fangtooth, which can be found at depths of over 5km, has the largest teeth of any fish in the ocean (proportionate to body size), helping it to capture as much prey as possible.



DISCOVER MORE

 For more TV, radio and events listings, check out **#BrainFood**, published every Friday on our website bit.ly/BBCFocusBrainFood



02 OPEN A CURIOSITY BOX

Science by post – it's one of those ideas that's so ingenious, we can't believe it hasn't been done before. The Curiosity Box is a new monthly subscription service that delivers experiments and science kits straight through the letterbox to curious kids around the world.

Developed by Renee Watson, founder of a science education company in Oxford, each month's themed box contains instructions and materials for hands-on experiments, as well as a piece of basic science kit (which will build up over time into a

home laboratory), and collectible cards featuring portraits of today's most inspiring scientists.

The project aims to bring Science, Technology, Engineering and Maths (STEM) activities into the home, inspiring children to think creatively and solve problems, while getting their families involved too. The theme of the first box, posting in August, is electricity, with experiments including illuminated putty sculptures, static electricity ping pong ball racing, and light-up greetings cards. To find out more, head to curiosity-box.com.

03 REDISCOVER GRAPHENE

WONDER MATERIALS: GRAPHENE AND BEYOND
MUSEUM OF SCIENCE AND INDUSTRY, MANCHESTER, 23 JULY 2016 – 25 JUNE 2017.

Ever since it first arrived in 2004, graphene has been hailed as a wonder material. This single layer of carbon atoms has a dream CV. It's 200 times stronger than steel, flexible, transparent, super conductive, and thinner than a human hair. We were told it would transform everything from energy storage and racing cars to water purification and wearable technology.

And yet, 12 years on, graphene still hasn't found its way into daily life. Was it all a load of hype? Well, whisper it quietly, but the revolution may finally be afoot. Last year saw the opening of the £61m National Graphene Institute at the University of Manchester, and just this June, the university launched a new company to develop and commercialise graphene-based products.

Now, explore the science, art and history of graphene for yourself in a new exhibition at Manchester's Museum of Science and Industry. Visitors will be able to discover the latest applications and have a go at imagining their own graphene products. Graphene gravy boat, anyone?



DON'T MISS

DOMESTIC SCIENCE

Matt Parker, Steve Mould and Helen Arney shine a light on the science of everyday life, from the bedtime cup of hot chocolate to the banana in your fruit bowl. Listen on BBC Radio 4, Wednesdays at 11:15pm.

04 TRAIN OUR TABBIES

Cats may have a reputation as wary, solitary creatures, but with a bit of patience even the most antisocial moggie can be trained – making life happier for both you and your cat. Feline behaviour expert Dr Sarah Ellis, co-author of a new book on the topic, reveals her top five tips...

THE TRAINABLE CAT BY JOHN BRADSHAW AND SARAH ELLIS IS OUT 4 AUGUST (£20, ALLEN LANE).

1 NEVER PUNISH A CAT

Cats learn best when they are rewarded: they don't tend to like people who punish them. They will try to repeat any behaviour they associate with positive feelings, so whenever a cat behaves well – whether that's staying calm during grooming, entering their cat carrier, or responding to a 'sit' command – immediately offer a reward.

2 NOTICE THEIR MOOD

It should be fairly obvious if your cat is disinterested in training – common signals include turning their head away, flopping slowly onto one side, or grooming in a rhythmic and systematic manner. Try to engage them by minimising distractions, offering tastier treats such as freshly cooked meat, or regularly switching between different types of rewards.

3 USE LURES

We all know that cats like to spend time relaxing and sleeping. If your feline friend doesn't volunteer his cooperation, lure him to the desired location with his favourite reward. If you want your cat to enjoy entering his carrier, for instance, drag a toy or move some food to the entrance. Once inside, don't forget to let him have his treat so that he associates entering the carrier with a positive feeling.

4 PICK THE BEST REWARDS

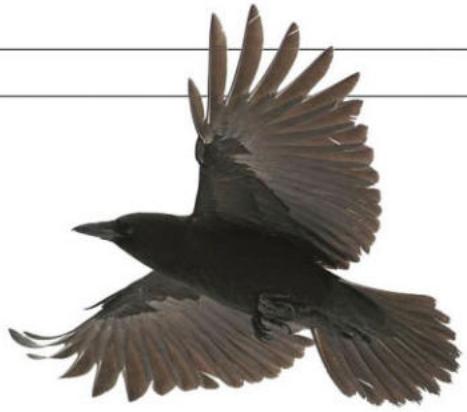
The biggest reward for a well-behaved cat is usually food. Cats are carnivorous by nature, so it's no surprise that little morsels of chicken, ham or fish are the most valued treats. Cats also love to play (it's the perfect outlet for their hunting instincts) and some enjoy being groomed and stroked – all of which can be used as additional rewards.

5 SET SUB-GOALS

Training usually fails when too much is expected of the cat, too soon. Break up any training goals into smaller sub-goals, offering a reward at each step. For example, if the goal is to get them used to your new vacuum cleaner, introduce them to it over several sessions, gradually increasing its volume and its proximity to the cat.

05

REDEFINE 'BIRD BRAIN'



Birds are cleverer than we give them credit for – that's the central message of a new book by cognitive biologist DR NATHAN EMERY. He speaks to JAMES LLOYD

BIRD BRAIN: AN EXPLORATION OF AVIAN INTELLIGENCE
BY DR NATHAN EMERY

IS OUT 4 AUGUST (£20, IVY PRESS).

Which are the smartest birds?

Bird intelligence is only about 20 to 25 years old as a serious field of study, so with a lot of birds we just don't know how smart they are yet. But in terms of more human-like, complex cognition, the focus so far has been on parrots and corvids – crows, ravens, rooks, jays, etc.

What makes these birds particularly smart?

There are three main areas where they excel. First, there's mental time travel – their ability to remember past events, such as what type of food they hid and where, and then use this information to make decisions about the future.

Second, there's what we call 'social cognition', which relates to their awareness of others. For example, we've shown that when western scrub jays cache food in the presence of other birds, they'll take steps to prevent it from being stolen. And finally, a number of species are able to make and use tools to solve problems. There was a famous New Caledonian crow called Betty who bent a piece of wire into a hook in order to reach food, and we've even observed rooks, who don't use tools in the wild, doing this in captivity. This is especially impressive, as they're demonstrating this behaviour spontaneously. Corvids and parrots are very good at adapting to new situations – that's what sets them apart.

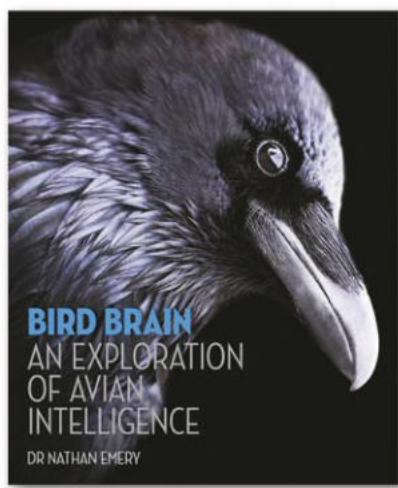
What's the most extraordinary example of bird intelligence that you've seen?

It can be overused – I talk about the remarkable behaviour of scrub jays when caching food. If another bird was watching, they'd try to protect their caches by moving them to a different place or hiding them behind a barrier. But what's really interesting is that only the birds who'd been thieves themselves in the past would do this – it's almost like their own experiences had taught them that the world is a bad place. Birds who hadn't stolen before didn't protect their caches, and so were more likely to have them stolen. This thieving behaviour might be akin to a 'theory of mind',

where the jays are able to think about the knowledge and intentions of their rivals.

Do you think we tend to underestimate the smartness of birds?

I think there are so many news stories coming out about their abilities that the term 'bird brain' is beginning to take on a new meaning. Even tiny, day-old chicks have shown a limited form of intelligence, being able to distinguish between smaller and larger numbers. But there's a broad spectrum of intelligence, and we still don't know that much about the majority of birds. I'm hoping to start working with ostriches, emus and rheas, but we don't have particularly high hopes for these species – they're the closest living relatives of the dinosaurs and are likely to have quite a primitive intelligence. But they might surprise us, as they must be reasonably capable to have survived for so long.



DR NEELOFER BANGLAWALA SHARES HER FAVOURITE SPOTS IN EDINBURGH



Edinburgh is a rare mix of modern city and rugged natural beauty. One moment you find yourself engrossed in the shops on Princes Street, the next you're lost in its hills or peaceful shores, oblivious that a city even exists. Steeped in cultural and academic history, Edinburgh is vibrant and cosmopolitan. It is also just the right size for cycling from one end to the other with 'nae bother'.

Every time I pass the **JAMES CLERK MAXWELL STATUE** 1 on George Street, I'm reminded of his genius. When we think of great scientists, most people think of Newton and Einstein, but Maxwell's name should also be on everyone's lips – he developed the theory of electromagnetism and was a truly brilliant thinker.

Another scientist from Edinburgh was John Napier, the father of logarithms. His former home **MERCHISTON TOWER** 2 is worth a visit. I also like nosing around **MACDONALD ARMOURIES** 3, where Paul Macdonald recreates swords from different historical periods. It's a great mix of history, engineering and martial arts.

I like the fact that, even in the city, you can find gems such as Craigleath Quarry. The upper part of the quarry face still remains, revealing the area's geological history.

If I feel like getting active in the city, I run, ramble or cycle along Union Canal, which has several beautiful aqueducts. It was on this canal that John Scott Russell observed a soliton – a single, pulse-like wave that holds its shape as it travels – and hence founded their study.

I like to walk up **CRAIGLOCKHART HILL** 4. People typically climb Arthur's Seat, but from Craiglockhart Hill you get a great view of Edinburgh, the River Forth and its bridges, and the surrounding Pentland Hills. On a clear day you can see right across to Fife.

For a bite to eat, nowhere beats **NILE VALLEY** 5 for its delicious wraps. I also love the friendly little Indian teahouse called **10 TO 10 IN DELHI** 6 – the perfect stop for a tasty masala chai. And for a night out, I head to The Caves for a bit of ceilidh in the old vaults. It's a great way to unleash your inner Scot! 

1 JAMES CLERK MAXWELL STATUE

A tribute to the Scottish scientist who developed the theory of electromagnetism. *George Street, EH2*

2 MERCHISTON TOWER

This is the former home of mathematician John Napier, inventor of logarithms and creator of a calculating device called 'Napier's bones'. *Colinton Road, EH10 5DT*

3 MACDONALD ARMOURIES

An armoury that makes traditional swords, knives and daggers. *Brunswick Street Lane, EH7 5JA* macdonaldarms.com/armoury

4 CRAIGLOCKHART HILL

A nature reserve in southwest Edinburgh offering beautiful woodland and views.

5 THE NILE VALLEY CAFE

A bustling cafe serving Sudanese and Middle Eastern food, located near many Fringe venues. *6 Chapel Street, EH8 9AY*

6 10 TO 10 IN DELHI

A laid-back Indian teahouse and restaurant. *67 Nicolson Street, EH8 9BZ*

Dr Neelofer Banglawala develops scientific software and is a member of ARCHER, the UK's national supercomputing service at the University of Edinburgh.



THE **FOCUS** COLLECTION

THE SECRETS OF NATURAL REMEDIES



In this special issue, the editors of *BBC Focus Magazine* put natural remedies under the microscope. From acupuncture to yoga, argan oil to zinc, we ask scientists which techniques and treatments will help you live a happier, healthier life and which you ought to avoid.

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SEPTEMBER
ISSUE
ON SALE
18 AUGUST

GENETICS

Are you a genetic superhero?

A recent study identified a tiny group of people who are resistant to inherited diseases. These 'genetic superheroes' could provide life-saving treatments, but there's one problem – we don't know who they are. Could you be one of them?

TOMORROW'S FOOD

THE AGE OF ARTIFICIAL MEAT

Three years ago, the first lab-grown burger was served up. It cost \$325,000 to make. Today, that price is coming down. We look at the race to create the first artificial meat factory.



PHOTOS: REUTERS, PRESS ASSOCIATION, GETTY X2

PSYCHOLOGY

IS CITY LIVING BAD FOR OUR MENTAL HEALTH?

Evidence is mounting that urban lifestyles are damaging our mental health. What's at the root of this effect, and what can we do about it?



OMG

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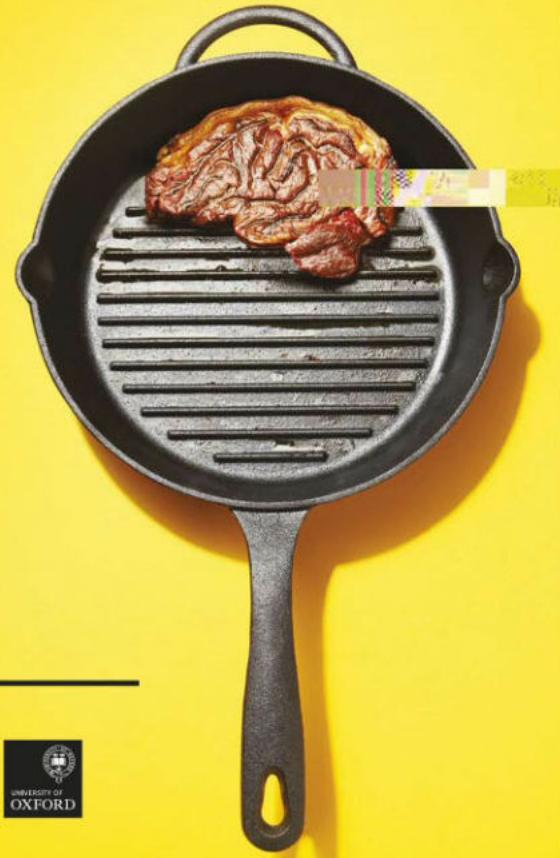
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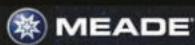
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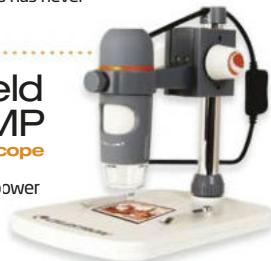


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“When *Top Gear* was looking to recreate the car chase in *The Italian Job*, they came to me”

Engineer Dr John Roberts talks to Helen Pilcher about rollercoasters, *Top Gear* stunts and his latest design project, the British Airways i360

I'm perhaps best known for my work on theme park rides and attractions. I've been a design engineer for most of my working life. The projects that I work on are challenging because each one is unique. There are no prototypes. You only get one chance to build them correctly and that's what keeps me interested.

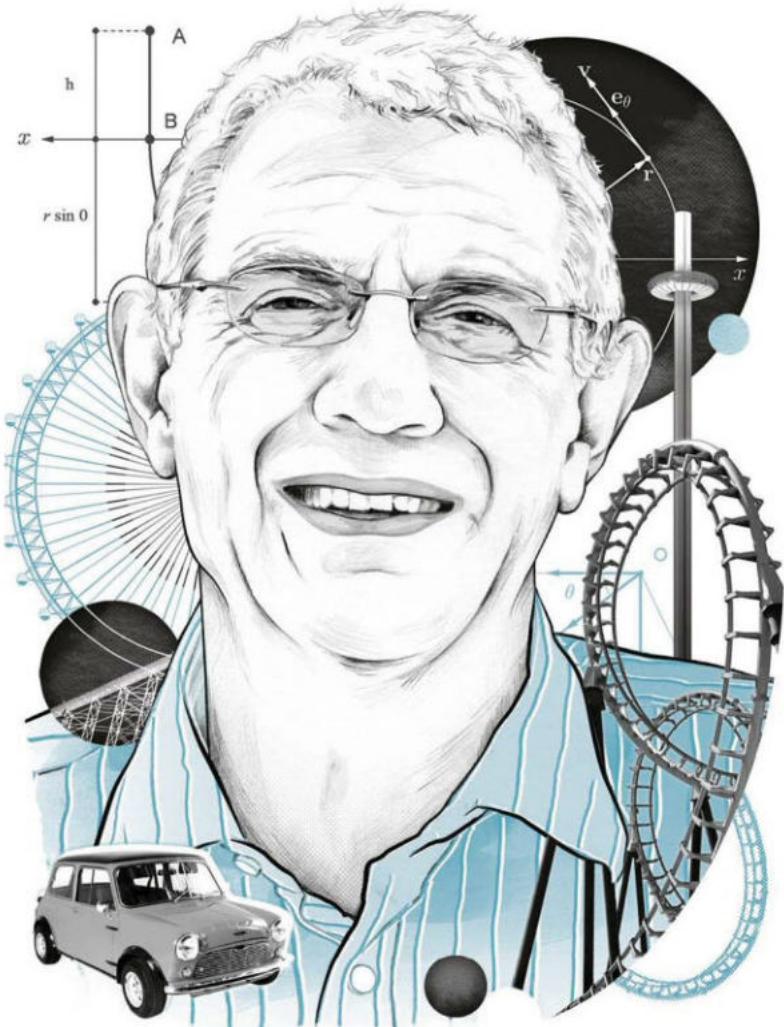
I became interested in engineering while I was still at school. I spent a summer holiday working on a construction site, digging holes in the ground and measuring the density of the soil. I worked 12 hours a day, seven days a week and made enough money to buy myself a Mini Cooper S. I was pretty pleased with that. But then I looked at the engineer driving around the site in his big, white Land Rover and wondered how much he was earning... and decided to study civil engineering at university.

I've designed a few rollercoasters, including the Big One at Blackpool Pleasure Beach. So when *Top Gear* was looking to recreate the car chase from *The Italian Job*, they came to me. They wanted to drive a car through a 360° rotation inside a tunnel... which is more or less the same as a rollercoaster but without the security of being clipped onto a track. I instructed the driver and even hand-painted the white line that he had to follow inside the tunnel.

I oversaw the design and construction of the London Eye. I've been on it hundreds of times but I'm probably a shocking person to share a capsule with. I get talking to people and then start telling them about it. They don't get much of a chance to look at the view.

This summer sees the opening of another of my projects, the British Airways i360 in Brighton. It's a 162m-tall observation tower that carries a moving doughnut-shaped glass pod. The pod can carry 200 people at a time and takes around 20 minutes to go up and come back down. The tower diameter is less than four metres, and it's just been awarded the Guinness Record for World's Most Slender Tower.

The British Airways i360 sounds simple but it's technically challenging. After all, it can be windy on the seafront in Brighton. So we've clad it in a specially-designed,



perforated aluminium shroud that reduces the wind pressure on the tower. And we've fitted 76 sloshing liquid dampers, which oppose any movement and help the tower to stand still.

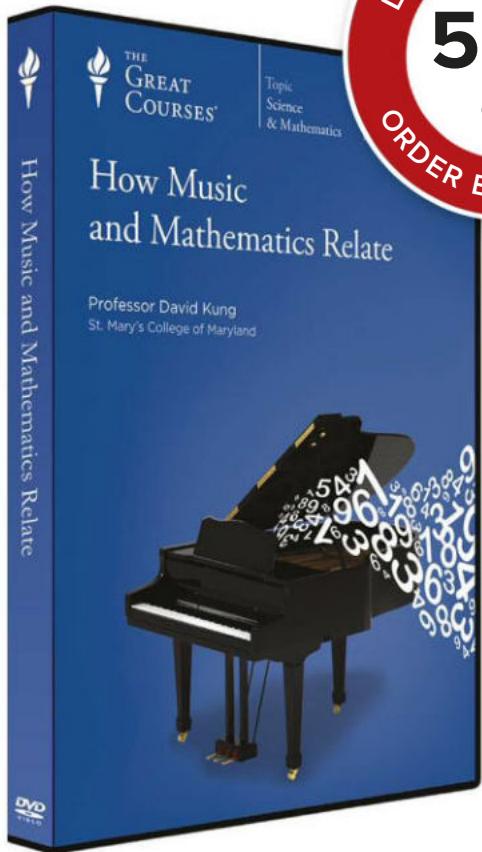
I'm dubious of engineers who aren't practically inclined. I can lay concrete, do plastering and turn my hand to woodwork. If there's one extra skill I'd like to learn, it's stone masonry. The thought of chipping away at a lump of rock. There's almost something primeval about it.

Dr John Roberts is a structural engineer and a visiting professor at the University of Manchester.

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NEXT ISSUE: ALICE GREGORY

I know it might sound a bit boring, but engineering is a job and a hobby. I plan to continue doing what I do for as long as I possibly can. 



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